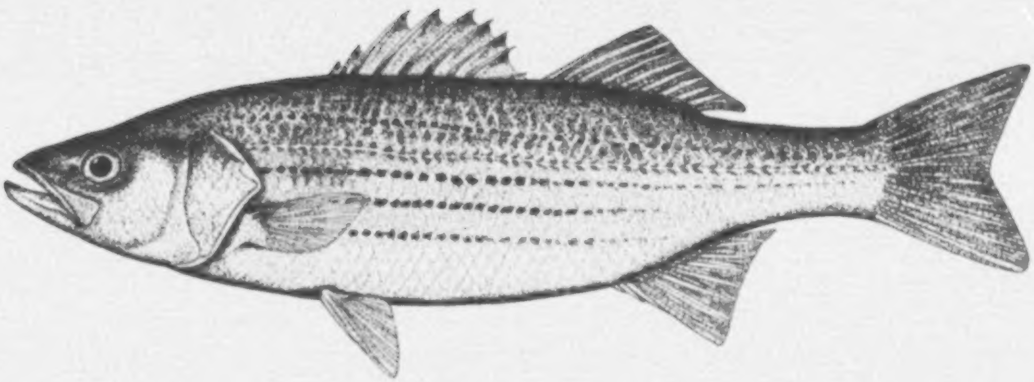
COSEWIC
Assessment and Status Report

on the

Striped Bass
Morone saxatilis

Southern Gulf of St. Lawrence population
Bay of Fundy population
St. Lawrence River population

in Canada



Southern Gulf of St. Lawrence population - SPECIAL CONCERN
Bay of Fundy population - ENDANGERED
St. Lawrence River population – ENDANGERED
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Previous report(s):

COSEWIC. 2004. COSEWIC assessment and status report on the Striped Bass *Morone saxatilis* inCanada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 43 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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Striped Bass — Illustration from Scott and Crossman, 1973.

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COSEWIC
Assessment Summary

Assessment Summary – November 2012
Common name
Striped Bass - Southern Gulf of St. Lawrence population
Scientific name
Morone saxatilis
Status
Special Concern
Reason for designation
This large-bodied fish has increased strongly in abundance recently, but is known from only a single spawning location and the population continues to be susceptible to high rates of poaching as well as by-catch in legal fisheries.
Occurrence
Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Atlantic Ocean
Status history
Designated Threatened in November 2004. Status re-examined and designated Special Concern in November 2012.

Assessment Summary – November 2012
Common name
Striped Bass - Bay of Fundy population
Scientific name
Morone saxatilis
Status
Endangered
Reason for designation
This large-bodied fish occurs at only a single known spawning location where it continues to be susceptible to exploitation from recreational fishing, by-catch in commercial fisheries, and from poaching. Habitat degradation continues in areas of historical spawning populations which limits recovery potential.
Occurrence
New Brunswick, Nova Scotia, Atlantic Ocean
Status history
Designated Threatened in November 2004. Status re-examined and designated Endangered in November 2012.

Assessment Summary – November 2012
Common name
Striped Bass - St. Lawrence River population
Scientific name
Morone saxatilis
Status
Endangered
Reason for designation
This population was assessed as Extirpated in 2004 and is the subject of a re-introduction effort, using fish from the Miramichi River, that has resulted in natural spawning, some increase in abundance, and an increase in distribution. It is, however, unclear if the population is self-sustaining without continued supplementation. The population is susceptible to by-catch in commercial fisheries, and although the threat of dredging has been reduced, it is still operating.
Occurrence
Quebec, Atlantic Ocean
Status history
Designated Extirpated in November 2004. Status re-examined and designated Endangered in November 2012.

COSEWIC
Executive Summary

Striped Bass
Morone saxatilis

Southern Gulf of St. Lawrence population
Bay of Fundy population
St. Lawrence River population

Wildlife Species Description and Significance

The Striped Bass (*Morone saxatilis*) is a large-bodied fish (1 m or more) with an olive green back, fading on the sides to silvery and becoming white on the belly. There are seven or eight horizontal dark stripes along each side. It has an elongate, laterally-compressed body, a triangular head, and a large mouth with a protruding lower jaw. It has two separated dorsal fins, the first of which is spiny and its caudal fin is forked. In Canada there are three designatable units (DUs): the southern Gulf of St. Lawrence DU, the Bay of Fundy DU, and the St. Lawrence River DU. The Striped Bass is a top aquatic predator in marine, estuarine, and freshwater habitats and has been the focus of important commercial and recreational fisheries and is of significance to Aboriginal fisheries and culture.

Distribution

The natural range of Striped Bass covers the Atlantic coast of North America from the St. Lawrence River to the St. Johns River in northeast Florida. The southern Gulf of St. Lawrence DU occurs in the southern Gulf of St. Lawrence, primarily on the east coast of New Brunswick, but also part of the coast of Nova Scotia, Prince Edward Island, and eastern Québec (Chaleur Bay and Gaspé), but there is only a single spawning population (Northwest Miramichi River). The Bay of Fundy DU occurs in the Bay of Fundy, New Brunswick, Nova Scotia and Atlantic Ocean. There is one confirmed spawning population in the Shubenacadie River, NS, possibly another in the Saint John River, NB, and one has been extirpated from the Annapolis River, NS. Historically, the St. Lawrence River DU occurred in Québec and adjacent portions of the Atlantic Ocean, but has been extirpated. A newly introduced population spawns in the Rivière-du-Sud basin at Montmagny, and uses the river section mostly between Lake Saint-Pierre and Rimouski (Ste-Luce), Québec.

Habitat

Striped Bass use a wide variety of habitats depending on the life stage. In most populations, spawning, incubation and early larval life occur in fresh or slightly brackish waters. Egg survival to hatching is closely tied to the physical and chemical properties of the incubation habitat, particularly water temperature, salinity, dissolved oxygen and the presence of a moderate current, which keeps the eggs suspended in the water column. At the juvenile and adult stages, Striped Bass uses coastal, estuarine and saltwater environments. In the fall, Striped Bass enter estuaries or freshwater habitats where they spend the winter. Wintering and spawning sites do not necessarily overlap in distribution or occur in the same drainage. In the spring, Striped Bass return to their spawning sites.

Biology

The Striped Bass is an anadromous species, spawning in freshwater and growing to maturity in the sea. Spawning commences as water temperatures rise above 10°C and may extend to 19°C in May and June. Female Striped Bass are highly fecund averaging 50,000 eggs per kg of body weight and can reach total lengths exceeding 1 m and ages older that 27 years in the southern Gulf of St. Lawrence. Fertilized eggs remain in suspension until hatching occurs in 2 to 3 days depending on the water temperatures. Larvae move to the near-shore habitats of estuaries where they grow rapidly and metamorphose to young-of-the-year (YOY); YOY progress downstream and into saltwater over the summer, and spread along the coasts. They cease feeding when water temperatures fall below 10°C when overwintering.

Population Sizes and Trends

Recent analyses suggest that in the Northwest Miramichi River, Striped Bass (Southern Gulf of St. Lawrence DU) spawner abundance increased from 3,000 to 5,000 in the late 1990s to annual averages of 35,000 (12,550 to 92,160) between 2001 and 2010, and 50,000 (16,200 to 92,160) between 2006 and 2010. The rate of increase over the last 18 years (1993 to 2010) has been about 500% with abundance estimates returning to levels last observed in 1994-95. The Bay of Fundy DU Striped Bass populations mix with American populations and this confounds status assessment. By-catch data from the Shubenacadie River American Shad fisheries suggest that Striped Bass spawner abundance has increased since 2001, which is consistent with expectations based on recruitment of the strong 1999 year class. Because the St. Lawrence River DU had been extirpated, the recovery target is defined as the re-establishment of a viable naturally reproducing population with the same area of occupancy and extent of occurrence as the previous population. Actions to achieve this target are underway and some Striped Bass introduced from the Mirimichi River have survived, show good growth, and are now reproducing.

Threats and Limiting Factors

In general, threats include overfishing (directed, by-catch, poaching), habitat loss and degradation (e.g., dredging and release of dredged material), contaminants (agricultural and/or industrial pollution), and migration barriers. A major limiting factor appears to be interannual variation in recruitment from unknown causes.

Protection, Status and Ranks

In November 2004, COSEWIC designated the Southern Gulf of St. Lawrence and Bay of Fundy DUs as Threatened and the St. Lawrence River DU as Extirpated. The St. Lawrence River DU was listed on Schedule 1 of the federal *Species at Risk Act* (SARA) as an Extirpated Population (June 2011), but the other DUs have no status under SARA. General status ranks (2005) are Extirpated in Québec and At Risk throughout the Maritime provinces. Striped Bass populations and habitat are currently protected under the *Fisheries Act* and the *Canadian Environmental Protection Act, 1999*. In Québec, fish habitat is also protected under the *Act Respecting the Conservation and Development of Wildlife*. NatureServe ranks the Striped Bass as globally secure; the St. Lawrence River DU is ranked as Extirpated in Canada, but the other two DUs have not been ranked nationally or provincially.

TECHNICAL SUMMARY - Southern Gulf of St. Lawrence population

Morone saxatilis

Striped Bass — Bar rayé

Southern Gulf of St. Lawrence population — Population du sud du golfe Saint-Laurent

Range of occurrence in Canada (province/territory/ocean): Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Atlantic Ocean

Southern Gulf of St. Lawrence, primarily on the east coast of New Brunswick, but also part of the coast of Nova Scotia, Prince Edward Island, and eastern Québec (Chaleur Bay and Gaspé). A single population spawning occurs in the Northwest Miramichi River, New Brunswick.

Demographic information

Generation time (average age at which males and females are mature) Based on dominant age class, but Striped Bass may continue breeding for up to 20 years in some areas	4 years
Is there a continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within 2 generations	Unknown
Estimated percent increase in total number of mature individuals over the last 3 generations increase over the last ~4 generations or 18 years (1993–2010)	+ 546%
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next 3 generations No *a priori* reason to think it will decrease	Unknown
Inferred percent increase in total number of mature individuals over any 3 generations period, over a time period including both the past and the future. At least stable to increasing	>10%
Are the causes of the decline clearly reversible and understood and ceased?	NA
Are there extreme fluctuations in number of mature individuals? Between 2006 and 2010, average number of spawners has ranged from 16,200 to 92,160	No

Extent and Occupancy Information

Estimated extent of occurrence 20,260 km² based on inclusion of a 10-km strip of coastal zone, Gaspé to Cape Breton Island	20,260 km²
Index of area of occupancy (IAO) (Always report 2 × 2 grid value) < 100 km² (area of single spawning ground in the Northwest Miramichi River)	< 100 km²
Is the total population severely fragmented?	No
Number of locations* Northwest Miramichi River	1
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No

* See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Probably not
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Southern Gulf of St. Lawrence population	According to the Bayesian hierarchical model (capture-mark-recapture using commercial gear in the Northwest Miramichi River), the average annual number of spawners: In the late 1990s: 3,000 to 5,000 Between 2001 and 2010: 35,000 (12,550 – 92,160) Between 2006 and 2010: 50,000 (16,200 – 92,160)
Total	On average, 50,000 spawners between 2006 and 2010

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Unknown

Threats (actual or imminent, to populations or habitats)

Illegal fishing and mortality from incidental catches in a variety of fisheries.

Rescue Effect (Immigration from outside Canada)

Status of outside population(s)? American populations have recovered since the implementation of management measures.	Improving
Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely? There is no evidence of movement of US-origin fish into the southern Gulf of St. Lawrence.	No, not without human intervention.

Status History

COSEWIC: Designated Threatened in November 2004. Status re-examined and designated Special Concern in November 2012.

* See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** Not applicable
Reasons for designation: This large-bodied fish has increased strongly in abundance recently, but is known from only a single spawning location and the population continues to be susceptible to high rates of poaching as well as by-catch in legal fisheries.	

Applicability of Criteria

Criterion A: Not applicable. Population appears to be increasing.
Criterion B: Meets Endangered for B2 as IAO (< 100 km^2) is below threshold. Meets Endangered for sub-criterion (a) as only one location, but no other sub-criteria (no evidence of continuing declines in any of b,c(i)-(iv).
Criterion C: Not applicable. No criteria met.
Criterion D: Not applicable. Does not meet criterion. Although there is only one known spawning population, there is no evidence of imminent threats to the population. **Criterion E:** Not done. Data unavailable for analysis.

TECHNICAL SUMMARY - Bay of Fundy population

Morone saxatilis
Striped Bass — Bar rayé
Bay of Fundy population — Population de la baie de Fundy
Range of occurrence in Canada (province/territory/ocean): Bay of Fundy, New Brunswick, Nova Scotia and Atlantic Ocean. One spawning population in the Shubenacadie River (Sh), possibly another in the Saint John River (Sj), and historically in the Annapolis River (A).

Demographic information

Generation time (average age at which males and females are mature) Based on dominant age class, but Striped Bass may continue breeding for up to 20 years in some areas	4 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Shubenacadie: Some evidence of increase since 2001, but large, natural, interannual variation in juvenile abundance persists Saint John: Genetic evidence of a spawning population, but no confirmation via captures of newly spawned young. Annapolis: No evidence of spawning	Probably not
Estimated percent of continuing decline in total number of mature individuals within 2 generations Shubenacadie: Indications that adult abundance has increased since 2001. Saint John: No historical information available to compare present status. Annapolis: No evidence of spawning in recent decades	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last 3 generations Shubenacadie: The data on by-catch suggest that the Striped Bass spawning abundance has increased since 2001 In 2002, 15,000 Striped Bass age 3+, of which 7,000 were age ≥ 4+. No other evaluation since.	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next 3 generations	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any 3 generations period, over a time period including both the past and the future	Unknown
Are the causes of the decline clearly reversible and understood and ceased? Shubenacadie: Yes, Saint John, unknown, Annapolis, No	Overall, no
Are there extreme fluctuations in number of mature individuals? Strong variation among year classes in Shubenacadie	Probably not

Extent and Occupancy Information

Estimated extent of occurrence Incorporates a 10 km strip of coastal habitat Sh: 13,550 km² (10 km from the shore) Sj: Bay of Fundy = 9,000 km² (10 km from the shore)	22,500 km²

Index of area of occupancy (IAO) (2 × 2 grid value) Sh: < 100 km² based on spawning habitat Others: unknown	< 100 km²
Is the total population severely fragmented?	No
Number of locations* Shubenacadie River, Saint John River (uncertain if reproducing), Annapolis River (extirpated)	1, possibly 2.
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? Regain of Saint John River spawning population requires confirmation	No
Is there an [observed, inferred, or projected] continuing decline in number of populations? Saint John River: The last capture of eggs and one young individual (1+) in the interior areas of Belleisle Bay date back to 1979. Annapolis River: Since 1971, very low recruitment and aging population structure of this population is observed.	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*? Disappearance of the spawning ground of the Annapolis River. Limited observation on the Saint John River.	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? Habitat continues to be compromised by migration barriers (e.g., Mataquac Dam on St. John River; causeway and tidal power plant on Annapolis River)	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	Unknown
Are there extreme fluctuations in index of area of occupancy?	Unknown

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Bay of Fundy (Shubenacadie River)	2002: 15,000 Striped Bass of ages 3+
Bay of Fundy (Saint John River)	Unknown
Bay of Fundy (Annapolis River) No reports of gravid fish	0?
Total	~15,000

* See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Unknown

Threats (actual or imminent, to populations or habitats)

For the Bay of Fundy DU, threats are associated with spawning failure in the Annapolis River. Abandonment of spawning ground could be attributable to causeway construction (1960) and operations of the Annapolis Tidal Station (beginning in 1984) causing shifts in flow regime and hydrology, and turbine mortality. Poor water quality is also reported as a threat but direct studies on the impacts of Annapolis River water on egg survival are limited. In the Saint John River, threats are either uncertain or low (poaching, commercial by-catch, fisheries impacts on habitat, fisheries on food supplies, aquaculture). Shubenacadie River Striped Bass are threatened by by-catch in many commercial fisheries and are exploited in a recreational fishery; the presence of the introduced Chain Pickerel in some overwintering sites may be a threat.

Rescue Effect (Immigration from outside Canada)

Status of outside population(s)? American populations have recovered since the implementation of management measures.	Improving
Is immigration known or possible? No evidence that fish from US actually spawn in Canadian waters	Yes
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Likely
Is rescue from outside populations likely?	Unlikely without human intervention.

Status History

COSEWIC: Designated Threatened in November 2004. Status re-examined and designated Endangered in November 2012.

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** B2ab(iii)
Reasons for designation: This large-bodied fish occurs at only a single known spawning location where it continues to be susceptible to exploitation from recreational fishing, by-catch in commercial fisheries, and from poaching. Habitat degradation continues in areas of historical spawning populations, which limits recovery potential.	

Applicability of Criteria

Criterion A: Not applicable. Does not meet any criteria.
Criterion B: Meets Endangered for B2 as IAO (<100km²) is below threshold. Meets Endangered for sub-criterion (a) as number of locations (1) is below threshold, and b(iii) as continued presence of causeway, tidal power plant, and dam represent continuing habitat degradation in areas of historical populations.
Criterion C: Not applicable. Does not meet criteria.
Criterion D: Meets Threatened for D2 as number of known locations (1) is below threshold and recruits to population(s) are susceptible to losses from by-catch in fisheries and in targeted recreational fisheries. **Criterion E:** Not applicable. Data unavailable to conduct analysis.

TECHNICAL SUMMARY - St. Lawrence River population

Morone saxatilis
Striped Bass — Nom commun en français: Bar rayé
St. Lawrence River population — Population de l'estuaire du Saint-Laurent
Range of occurrence in Canada (province/territory/ocean): Québec and Atlantic Ocean that spawns in Rivière-du-Sud basin at Montmagny, and uses the river section mostly between Lake Saint-Pierre and Rimouski (Ste-Luce).

Demographic information

Generation time (average age at which males and females are mature) Based on dominant age class, but Striped Bass may continue breeding for up to 20 years in some areas	4 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Re-introduction too recent to see if increase from 0 is sustainable	Unknown
Estimated percent of continuing decline in total number of mature individuals within 2 generations	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations] Unknown, but an increase from 0 has occurred over the last 10 years following re-introduction efforts.	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next 3 generations Re-introduction efforts are too recent (since 2002) to project trends	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any 3 generations period, over a time period including both the past and the future	Unknown
Are the causes of the decline clearly reversible and understood and ceased? The initial collapse was never attributed to a cause or causes with certainty	No
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence Re-introduced fish appear to be expanding across the historical extent of occurrence but unknown if sustainable	Formerly ~3,000 km^2
Index of area of occupancy (IAO) (Always report 2x2 grid value)	Unknown, but likely < 100 km^2
Is the total population severely fragmented?	No

Number of locations* Historically, 300 km section (Lake Saint-Pierre – Kamouraska); now confirmed spawning in Rivière-du-Sud basin at Montmagny. Otolith microchemistry suggests that 1-2 other spawning areas may exist	Probably 1
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence? Re-introduced fish appear to be expanding across the historical extent of occurrence but unknown if sustainable	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? Re-introduced fish appear to be expanding across the historical area of occupancy, but unknown if sustainable	No
Is there an [observed, inferred, or projected] continuing decline in number of populations? Re-introduced fish appear to be expanding across the historical range, but unknown if sustainable	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*? Re-introduced fish appear to be expanding across the historical range, but unknown if sustainable	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? Release of dredged material continues although situation (degree, extent of decline) appears to have improved over the last 10 years	Probably
Are there extreme fluctuations in number of populations? Re-introduced fish appear to be expanding across the historical range, but unknown if sustainable	No
Are there extreme fluctuations in number of locations*? Re-introduced fish appear to be expanding across the historical range, but unknown if sustainable	No
Are there extreme fluctuations in extent of occurrence? Re-introduced fish appear to be expanding across the historical range, but unknown if sustainable	No
Are there extreme fluctuations in index of area of occupancy? Re-introduced fish appear to be expanding across the historical range, but unknown if sustainable	No

Number of Mature Individuals (in each population)

Population	**N Mature Individuals**
St. Lawrence River (G. Verreault, MRNF)	~1,000–1,500
Total	~1,000–1,500

* See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years]	Unknown

Threats (actual or imminent, to populations or habitats)

The factors explaining the extirpation of the St. Lawrence River DU remain unknown. Threats to current population include habitat degradation (some dredging and release of dredged material), changes in flow conditions, and by-catch in commercial fisheries.

Rescue Effect (Immigration from outside Canada)

Status of outside population(s)? American populations have recovered since the implementation of management measures.	Improving
Is immigration known or possible? It is unlikely without active intervention in the St. Lawrence River, and there was no evidence of rescue between 1968, when the last adult Striped Bass was observed, and 2002 when population augmentation began.	Unlikely
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Likely
Is rescue from outside populations likely? There are many indicators (genetic and tagging studies) that Striped Bass in the southern Gulf of St. Lawrence, the Bay of Fundy and of US origins do not use the St. Lawrence River for any purpose.	Unlikely without human intervention

Current Status

COSEWIC: Designated Extirpated in November 2004. Status re-examined and designated Endangered in November 2012.

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** B1ab(iii)
Reasons for designation: This population of a large-bodied fish was assessed as Extirpated in 2004 and is the subject of a re-introduction effort, using fish from the Miramichi River, resulting in natural spawning, some increase in abundance, and an increase in distribution. It is, however, unclear if the population is sustainable without continued supplementation. The population is susceptible to by-catch in commercial fisheries, and although the threat of dredging has been reduced, it is still operating.	

Applicability of Criteria

Criterion A: Not applicable. Does not meet criteria.
Criterion B: Meets Endangered for B1 as EO (~3,000 km^2) is less than the threshold, meets sub-criteria ab(iii) as there is only a single known spawning location and there is an inferred continuing decline in habitat quality owing to dredging operations.
Criterion C: Not applicable. Does not meet criteria.
Criterion D: Meets Threatened D2 as there is only a single confirmed spawning location and fish are susceptible to by-catch in some commercial fisheries and habitat degradation from dredging. Probably meets Threatened D1 as population estimate (1,000-1,500) is close to threshold and is highly uncertain. **Criterion E:** Not applicable. No data available for analysis.

PREFACE

In November 2004, COSEWIC recommended Threatened status for the southern Gulf of St. Lawrence and Bay of Fundy DUs and extirpated status for the St. Lawrence River DU. Since the publication of the COSEWIC recommendations (COSEWIC, November 2004), the St. Lawrence River DU was included on Schedule 1 of SARA (June 2011) as an Extirpated population. The Gulf of St. Lawrence and the Bay of Fundy DUs, however, have not been afforded legal protection under the federal *Species at Risk Act* (SARA).

Since 2004, joint research and management efforts have been made with the objective of improving the state of knowledge and management of Canadian populations. In 2006, Fisheries and Oceans Canada (DFO) conducted a Striped Bass recovery potential assessment to provide scientific data to support scenarios for listing the three designatable units on the List of Wildlife Species at Risk under SARA (DFO 2006). Since 2004, the state of St. Lawrence River Striped Bass DU has changed; stocking efforts have continued and while there is evidence of successful spawning (DFO 2009) the long-term status of the reintroduced population is unclear. In 2009, the authorities responsible for safeguarding species at risk in Québec (ministère des Ressources naturelles et de la Faune, MRNF) and federally (DFO) agreed to pool their resources and expertise to develop a recovery strategy for the St. Lawrence River Striped Bass for inclusion in the Species at Risk Public Registry. The advisory committee then submitted an allowable harm assessment (DFO 2009) and an exercise to identify the characteristics of the habitat that could be considered important to this Striped Bass population (DFO 2010b).

A listing and reclassification recommendation for the newly introduced population was made through an order-in-council (Government of Canada 2010). The St. Lawrence River population, however, is still considered Extirpated. The Recovery Strategy for the St. Lawrence River population was published in 2011 (Robitaille *et al.* 2011).

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2012)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada — Environnement Canada
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Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Striped Bass
Morone saxatilis

Southern Gulf of St. Lawrence population
Bay of Fundy population
St. Lawrence River population

in Canada

2012

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Morone saxatilis* (Walbaum 1792)

Family: Moronidae

Synonyms (taken from Scott and Crossman 1973):

Perca saxatilis	Walbaum 1792: 330 (type locality-New York)
Labrax notatus	Richardson 1836: 8
Perca labrax	Perley 1852: 22
Labrax Lineatus	Perley 1852: 181
Labrax lineatus	Fortin 1864: 60
Roccus lineatus	Adams 1873: 248
Roccus Lineatus Gill	Adams 1873: 304
Roccus lineatus (Bloch)	Gill Cox 1896b: 70
Morone	Whitehead and Wheeler 1967: 23
Roccus saxatilis (Walbaum)	Scott and Crossman 1969: 22

English common names:	Striped Bass Striper Bass Striper Rockfish Rockfish Striper Rock Linesides
French common names:	*bar rayé* *bar d'Amérique* *bar du Saint-Laurent*

Morphological Description

The Striped Bass (*Morone saxatilis*) has an elongate, laterally compressed body, a triangular head and a large mouth with a protruding lower jaw (many small teeth). It has two separated dorsal fins, the first of which is spiny (Figure 1). Its caudal fin is forked, and its anal fin has three spines and 9 to 11 soft rays (Scott and Crossman 1973; Bernatchez and Giroux 2000). Its pelvic fins are located in the thoracic position, and the cheeks and opercles are covered with scales (Figure 1). The Striped Bass is dark olive green (rarely pale green) to steel blue or black above, fading to silvery (sometimes with coppery reflections) on the sides, and becoming white on the belly. There are seven to eight horizontal, dark stripes along each side, following the scale rows. None of the stripes extend onto the head (Figure 1).

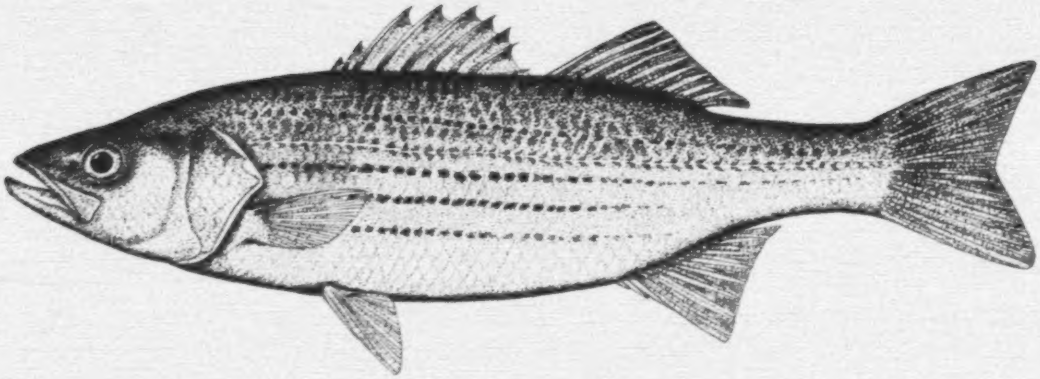

Figure 1. Striped Bass, *Morone saxatilis*. Illustration from Scott and Crossman, 1973.

Population Spatial Structure and Variability

In Canada, Striped Bass are considered to have spawned historically in five areas of eastern Canada (Figure 2): the St. Lawrence River (Québec), the Miramichi River estuary in the southern Gulf of St. Lawrence, and the Saint John, Annapolis and Shubenacadie river estuaries in the Bay of Fundy (COSEWIC 2004).

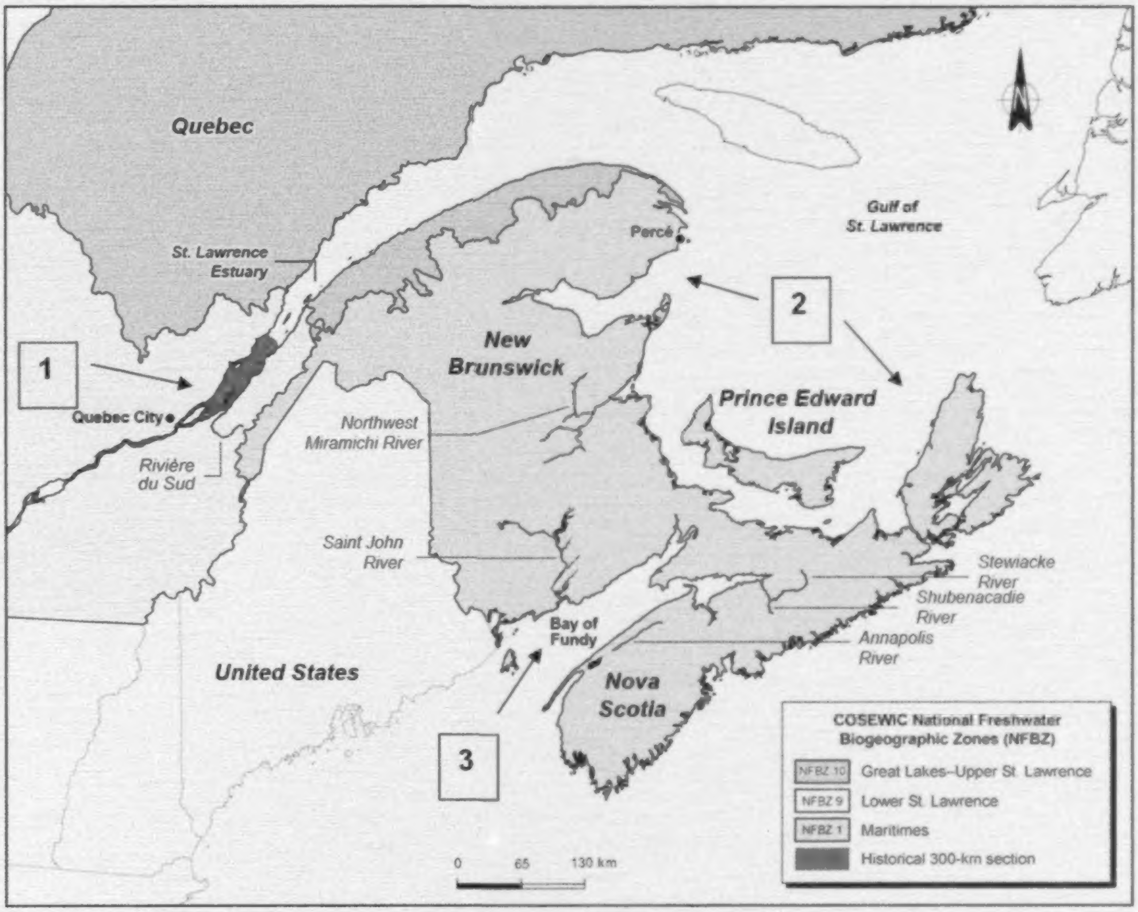

Figure 2. Canadian range of Striped Bass based on COSEWIC National Freshwater Biogeographic Zones. Three designatable units are defined: 1) the St. Lawrence River; 2) the Southern Gulf of St. Lawrence (Miramichi River); and 3) the Bay of Fundy (Shubenacadie River, Saint John River, Annapolis River).

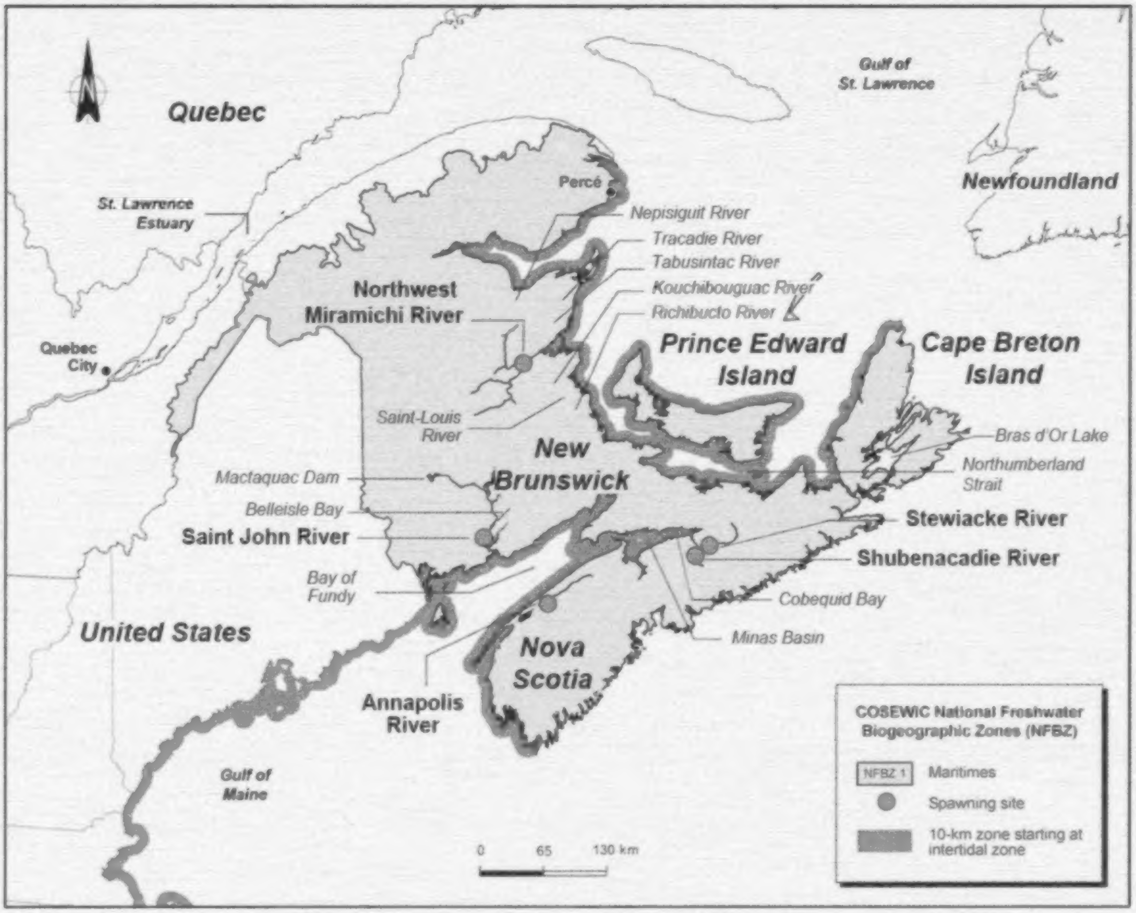

Figure 3. Maritimes National Freshwater Biogeographic Zone: populations of the Northwest Miramichi River and Bay of Fundy (Shubenacadie, Saint John and Annapolis rivers) and areas of interest for the study of Canadian Striped Bass populations. A 10-km area of the continental shelf was identified. The Annapolis River spawning population is considered to be extirpated.

Southern Gulf of St. Lawrence DU

The Southern Gulf of St. Lawrence population spawns only in the Northwest (NW) Miramichi River. Although Striped Bass have been captured in a number of estuaries in the southern Gulf of St. Lawrence, including the Nepisiguit, Miramichi, Kouchibouguac, Kouchibouguacis (St. Louis), Tabusintac, Tracadie, Cascapedia, Richibucto and Hillsborough rivers and Chaleur Bay (Melvin 1991; ZIP 2010; AVC Inc. 2003, cited in Douglas and Chaput 2011a; Robinson *et al.* 2004; Thistle 2011), no eggs or larvae have ever been collected elsewhere in the range of the DU. The Striped Bass marked at various locations were recaptured in the NW Miramichi River system during the spawning period. Striped Bass implanted with acoustic transmitters exhibited fidelity to the Miramichi River during the spawning period (Douglas *et al.* 2009). Using microsatellite nuclear DNA and mitochondrial DNA analyses, Robinson *et al.* (2004) have shown that YOY captured in several coastal sites south of the Miramichi River

system are genetically similar to one another, even though their capture sites ranged from the Miramichi River to the Richibucto River. Current knowledge indicates that all southern Gulf Striped Bass comprise a single population that spawns in the Northwest Miramichi River estuary (Bradford *et al.* 1995; Robichaud-LeBlanc *et al.* 1996; Douglas *et al.* 2003). This population is distinct from all other Striped Bass populations, including the American populations that venture into Canadian waters and the population that spawns in the Stewiacke River (Shubenacadie River system, Bay of Fundy DU) in Nova Scotia (Wirgin *et al.* 1993, 1995; Robinson *et al.* 2004; Douglas and Chaput 2011b). The specific hydrological conditions of the Miramichi River estuary may account for the egg and larval developmental success in this population (Douglas *et al.* 2009).

Bay of Fundy DU

No spawning activity has been observed and no eggs, larvae or juveniles have been captured in the Saint John River in irregular searches spanning more than 30 years (Jessop 1995; Douglas *et al.* 2003). The last Striped Bass eggs were reportedly collected in 1979 in the interior areas of Belleisle Bay (Douglas *et al.* 2003). Surveys were unsuccessful in collecting eggs, larvae or juveniles during 1992 and 1994 (Jessop 1995), or in collecting YOY Striped Bass in 2000 and 2001 (Douglas *et al.* 2003), and 2009 (DFO 2011). On the Annapolis River, no viable spawning has taken place since 1976, with egg survival in the natural environment being considered marginal (Jessop 1990, 1995). In sampling carried out in 2001, 2002, 2009 and 2010, no juveniles were detected (Douglas *et al.* 2003; Bradford and LeBlanc 2011). The Shubenacadie River Striped Bass population is the only population in the Bay of Fundy where annual spawning has been verified with variable reproductive and recruitment success depending on environmental conditions (Bradford and LeBlanc 2011). Bentzen *et al.* (2009; Table 1) conducted a genetic study of Striped Bass. They assayed 11 microsatellite loci in nearly 1,500 DNA samples. The samples used were collected from the Shubenacadie River (juveniles; N = 90), the Miramichi River (juveniles and adults; N = 81), in American populations [Hudson River (adults; N = 94); Kennebec River (juveniles; N = 48) and Chesapeake Bay (juveniles; N = 93)], the Annapolis River (adults, N = 111; 1972; 1975; 1976; 1978; 1981), and several samples from the Saint John River (downstream from the Mactaquac Dam (1999–2006; N=739); Belleisle Bay (2003; N=57); Lower Saint John River (2008; N=14; juveniles > 1 year of age).Through Bayesian analysis, four groups were identified: American populations, the Shubenacadie River population, the Miramichi River population, and a fourth group of fish from the Saint John River that were distinct from all other groups and which may represent a residual "native" population. The samples from the Saint John River also contained fish that were very similar to fish sampled from US and Shubenacadie spawning areas. In 1999 and 2000 samples, most fish sampled from the Saint John River appeared to be native whereas, since 2001, fish genetically similar to the Shubenacadie River population has dominated samples from the Saint John River.

Table 1. Genetic differentiation based on F_{st} estimated from variation across 11 genotyped microsatellite loci in juvenile Striped Bass from a number of catch sites. All pairwise F_{st} estimates except Shu vs SJR/SHU comparison are statistically significant at P < 0.001. Shu = Shubenacadie River, MIR = Miramichi River, SJR = Saint John River, ANN = Annapolis River, US = United States.

Dataset	Shu	Mir	SJR/SJR	SJR/SHU	SJR/US	ANN	SJR/MIX[8]
US[1]	0.04	0.0920	0.0457	0.0546	0.0036	0.0024	0.0175
Shu[2]		0.1271	0.0630	0.0013	0.0551	0.0457	0.0240
Mir[3]			0.1218	0.1364	0.1128	0.0991	0.1108
SJR/SJR[4]				0.0625	0.0476	0.0380	0.0147
SJR/SHU[5]					0.0597	0.0524	0.0260
SJR/US[6]						0.0046	0.0201
ANN[7]							0.0130

Source: Bentzen *et al.* (2009) and Bradford *et al.* (2012)

1: US: United States (Chesapeake Bay; Hudson River; Kennebec River)
2: Shu: Shubenacadie River
3: Mir: Miramichi River
4: SJR : Saint John River (majority from near Mactaquac Dam, Belleisle Bay, lower Saint John River), SJR/SJR: fish sampled in SJR that were identified genetically as belonging to the putative 'native' SJR population,
5: SJR/SHU: fish sampled in SJR that were genetically identified as having come from SHU
6: SJR/US: fish sampled in SJR that were genetically identified as having come from the US
7: ANN: Annapolis River
8: SJR/MIX: fish sampled in SJR that looked (based on their DNA) like they were the result of 'native' SJR bass interbreeding with fish that came either from SHU or US.

With respect to extirpated populations, the Annapolis River (1972–1981) population could not be well discriminated from American populations which suggests that they may be strays from the US. In addition, DNA could not be obtained for the extirpated St. Lawrence River fish. The Miramichi River population was distinct from the other populations, whereas the Shubenacadie River and Saint John River (putative native fish) populations are slightly more divergent from each other than either is from American populations (Table 1, Bentzen *et al.* 2009; Bradford *et al.* 2012).

St. Lawrence River DU

The third DU also comprises a single population, that of the St. Lawrence River. While the original DU was extirpated, a new population is now considered to be becoming established in the area historically occupied by the St. Lawrence River DU (Pelletier *et al.* 2011, Bujold and Legault, 2012), and capable of reproducing (Legault, 2012). The new population has been established via reintroduction efforts initiated in 2002 using Striped Bass juveniles collected in the Miramichi River (southern Gulf of St. Lawrence population). Fish were either directly translocated as YOY, or artificially reared and propagated at the government fish culture station in Baldwin Mills.

Historically, the isolation of the now-extirpated population from the other Canadian populations was deduced primarily from capture-mark-recapture studies. Of 3,009 specimens tagged between 1944 and 1962 (Beaulieu 1962; Robitaille 2001; COSEWIC 2004), 310 were recaptured, all in the roughly 300-km section between Lake Saint-Pierre and Kamouraska. This section corresponds to the portion of the St. Lawrence in which all historical captures of Striped Bass by recreational anglers and commercial fishers were reported. Because no Striped Bass captures have ever been reported downstream from Kamouraska (Beaulieu 1962; Robitaille 2001), it is considered that the St. Lawrence River Striped Bass are isolated from the other Atlantic coast populations. This does not rule out the possibility of contact between fish from these areas, but any contact would appear to be the exception. The case for isolation is supported by the fact that, although commercial catches of Striped Bass were recorded on a continuous basis from 1920 to 1965 in the St. Lawrence River, there were no catches of Striped Bass during the same period in the range of the Southern Gulf of St. Lawrence DU (from 1935 to 1968; Douglas *et al.* 2003). In the 1980s, catches of several dozen Striped Bass around the Gaspé Peninsula and in the middle St. Lawrence River suggested the recovery of the local population (COSEWIC 2004). Therefore, it is considered that the captures of Striped Bass in the Chaleur Bay and Gaspé area were actually Striped Bass from the Miramichi River population, based on tagging (Bradford and Chaput 1996; Douglas *et al.* 2003). Since 2008, the increase in abundance in the Miramichi is reflected by higher catch of Striped Bass in the Chaleur Bay and Gaspé area (from Restigouche to Gaspé; V. Bujold, MRNF, pers. comm. April 2012).

Designatable Units

In Canada, three designatable units (DUs) are proposed for the Striped Bass: the Bay of Fundy, the Southern Gulf of St. Lawrence and the St. Lawrence River DUs. Two of the DUs satisfy the discrete criterion of COSEWIC (2010a) guidelines as they exist within separate National Freshwater Biogeographic Zones (NFBZ): the Great Lakes/Upper St. Lawrence and Lower St. Lawrence River NFBZ (St. Lawrence River DU) and the Maritimes NFBZ (Southern Gulf of St. Lawrence and Bay of Fundy DUs). The Southern Gulf of St. Lawrence DU is discrete from the Bay of Fundy DU based on tagging information and mitochondrial and nuclear DNA analysis (Bentzen *et al.* 2009; Bradford *et al.* 2012). It was also discrete from the extirpated St. Lawrence River DU based on mark-recapture data.

The Bay of Fundy DU comprises the known population of the Shubenacadie River, Nova Scotia, and a possible spawning population in the Saint John River population in New Brunswick. In addition, Striped Bass also use the Annapolis River to feed, but no successful spawning has been observed since at least 1976.

The St. Lawrence River DU now consists of the newly introduced St. Lawrence River population. This new population has been introduced through the hatchery supplementation using Striped Bass from the Miramichi River (Pelletier 2009; Pelletier *et al.* 2009; 2010), and by direct translocations of YOY. The St. Lawrence River population, however, is considered as a unique DU, both in term of ecology and

evolution. There is no current evidence of the presence of effective natural migration between the Southern Gulf of St. Lawrence DU and the St. Lawrence River DU. In terms of ecological habitat, there is a sharp decline in Striped Bass habitat use east of Kamouraska, where the habitat characteristics are different (sediment, body of water, temperature) from the area of Anse Sainte-Anne at La Pocatière (Pelletier *et al.*, 2010). The distribution pattern of the newly introduced population is similar to what was observed from specimens of the extirpated population and is significantly different from the Miramichi River population (Douglas *et al.* 2006; Pelletier *et al.* 2011). Thus, current observations suggest reproductive isolation due to geographic isolation of the two DUs (see **Population Spatial Structure Variability** section). The newly introduced Striped Bass population in the St. Lawrence River seems to be expanding across the original geographic range of the extirpated population (Pelletier 2009; Pelletier *et al.* 2009, 2010), has reproduced naturally at at least one site (mouth of Rivière du Sud basin at Montmagny), and produces offspring that survive in the system (Legault 2012).

Overall, the distinctive environments in which fish from each of the DUs exits for the marine nearshore and freshwater phases of their life history (St. Lawrence River and northern Gulf of St. Lawrence; southern Gulf of St. Lawrence and Miramichi River; Bay of Fundy), the distinct dispersal patterns required of individuals to persist in these areas, the confirmed natural reproduction and spawning grounds of this population within the St. Lawrence River all suggest some degree of reproductive isolation due to geographic isolation of the two populations within each DU and the evolutionary significance of recognition of distinct DUs. As a re-introduced population, Striped Bass in the St. Lawrence River qualifies for inclusion in the assessment of Striped Bass as per COSEWIC guidelines (i.e., numbers 3,7 regarding intralimital re-introductions for conservation purposes) on manipulated populations according to Appendix E7- *COSEWIC Guidelines on Manipulated Populations* (COSEWIC, 2010) and is considered to stand as a DU.

Tagging data and generic analyses suggest that Striped Bass that spawn in American east coast rivers intermingle with Canadian fish in the Bay of Fundy (Melvin 1978; Dadswell *et al.* 1984; Hogans 1984; Harris and Rulifson 1988; Waldman *et al.* 1988; Wirgin *et al.* 1993, 1995; Diaz *et al.* 1997; Robinson 2000; Robinson *et al.* 2004; Bradford *et al.* 2012). These mixed populations occur in the marine waters of the Bay of Fundy and some American origin fish may enter the Saint John and Annapolis rivers. Consequently, there a fourth DU may exist in Canadian waters: fish that spawn in American rivers. Given that they intermingle with Canadian fish and that any estimates of numbers or trends would require partitioning of mixtures of fish into those of Canadian and non-Canadian origin where they co-occur, information that is not readily available at present, this report does not discuss or assess fish from this putative fourth DU.

Special Significance

The Striped Bass is an important top predator of coastal marine habitats and given its anadromous life cycle, provides a link between freshwater, estuarine, and marine habitats. It has, and in some areas still is, been the focus of locally important recreational, commercial, and Aboriginal fisheries.

DISTRIBUTION

Global Range

The natural range of Striped Bass covers the Atlantic coast of North America from the St. Lawrence River to the St. Johns River in northeastern Florida (Scott and Crossman 1973; Scott and Scott 1988). Native populations of Striped Bass have also existed in Gulf of Mexico tributaries, from the Suwannee River in northwest Florida to Lake Pontchartrain in Louisiana (Lee *et al.* 1980; Bain and Bain 1982).

In 1879, Striped Bass were introduced to the shared estuary of the Sacramento and San Joaquin rivers, California, on the United States Pacific coast (Bonn *et al.* 1976). From that first group, populations gradually became established in rivers on the west coast of the United States (Hart 1973; Lee *et al.* 1980; Setzler *et al.* 1980) and occasionally enter Canadian Pacific waters (Hart 1973).

The species can live in freshwater and, in some cases, complete its life cycle in this habitat (Scruggs 1957). It has been introduced as a recreational fish to several lakes and reservoirs around the world, with varying degrees of success (Lee *et al.* 1980; Setzler *et al.* 1980). In some locations, naturally spawning populations have become established. Elsewhere, Striped Bass grow well but cannot spawn: ongoing stocking programs are therefore required to support fishing activity (Lee *et al.* 1980).

The largest concentrations of Striped Bass are found in the centre of the species' range, namely Chesapeake Bay in Maryland, the Hudson River in New York and the Delaware River in Maryland (Douglas *et al.* 2003).

Canadian Range

In Canada, Striped Bass is at the northern limit of its North American range and Canadian populations are exclusively anadromous. It is reported that these populations historically spawned in five rivers: the Saint John and Miramichi rivers in New Brunswick, the Annapolis and Shubenacadie rivers in Nova Scotia and the St. Lawrence River in Québec. They occur in three national freshwater biogeographic zones (NFBZs), as defined by COSEWIC: the Great Lakes–Upper St. Lawrence (NFBZ 10), the Lower St. Lawrence (NFBZ9) and the Maritimes (NFBZ1) (Figure 2).

Wintering and spawning sites do not necessarily overlap in distribution or occur in the same drainage (DFO 2006). The extent of occurrence (EO) of the three DUs has incorporated a 10 km wide buffer of nearshore marine habitat and has been estimated as 44,810 km^2. The total index of area of occupancy (IAO, 2 km x 2 km grid) has been estimated based on spawning areas in freshwater as ~ 200 km^2.

Southern Gulf of St. Lawrence DU

The EO of Striped Bass in the southern Gulf of St. Lawrence comprises the coastal area of the entire southern Gulf of St. Lawrence (Douglas and Chaput 2011a,b). Catches of immature and adult Striped Bass have been reported in Québec, New Brunswick, Nova Scotia and Prince Edward Island. Using capture-mark-recapture and commercial landings data, Douglas *et al.* (2003) established the extent of occurrence of Striped Bass in the southern Gulf. It is defined by the coastal areas of Percé (Québec) in the northwest, to Chéticamp (Cape Breton, Nova Scotia) in the east, and to Prince Edward Island in the north (DFO, 2011). Given that southern Gulf Striped Bass use primarily coastal areas and are uncommon in freshwater the extent of occurrence should be defined as a 10-km band starting from the intertidal zone along the coasts between Gaspé and Cape Breton, including Prince Edward Island. Consequently, the EO is estimated as 20,260 km (from Gaspé Cape to Cape North, Cape Breton Island, excluding St. Paul Island; D.K. Cairns, DFO, pers. comm., Cairns *et al.* 2012). The IAO has been estimated as < 100 km^2 given that spawners from the southern Gulf of St. Lawrence DU consistently use a single spawning site, i.e., the Northwest Miramichi River estuary. The number of locations is considered to be one as there is only one known spawning locality in the Northwest Miramichi River where local habitat perturbations could place the population at risk. In addition, while fisheries (by-catch and directed) are more dispersed threats, they function together to reduce escapement to a single spawning population.

Bay of Fundy DU

The native populations of the Bay of Fundy occur or, once occurred, in the Shubenacadie and Annapolis rivers in Nova Scotia, and in the Saint John River in New Brunswick. Recent genetic studies confirm that the extent of occurrence of the Shubenacadie population extends at least to the Saint John River, New Brunswick (Bentzen *et al.* 2009; Bradford *et al.* 2012), but the Annapolis River spawning population is considered extirpated (DFO 2006).

The simultaneous presence of bass of Canadian and American origin in the Bay of Fundy has been demonstrated by the analysis of meristic and morphometric characters, recaptures of tagged specimens, the frequency of certain parasites, blood protein electrophoresis and mitochondrial or nuclear DNA analysis (Melvin 1978; Dadswell *et al.* 1984; Hogans 1984; Harris and Rulifson 1988; Waldman *et al.* 1988; Wirgin *et al.* 1993, 1995; Diaz *et al.* 1997; Robinson 2000; Robinson *et al.* 2004; Bradford *et al.* 2012).

In the Shubenacadie River system, Striped Bass spawn in the Stewiacke River, approximately 3 to 6 km upstream from the confluence of the two rivers near the saltwater-freshwater interface (Rulifson and Tull 1999). The extent of occurrence for the Shubenacadie River population can be determined from recaptures of Striped Bass tagged in the system between 1999 and 2002, samples of Striped Bass genotyped between 1999 and 2006 (Bradford *et al.* 2012), and by genotyping of DNA from preserved Striped Bass tissue (Bradford and LeBlanc 2011). According to the latest genetic assessment by Bradford *et al.* (2012) the area corresponds to the zone between the Gulf of Maine and the southern Atlantic coast of Nova Scotia, and not just the zone between the Shubenacadie River and the Saint John River (DFO 2006). The EO of this zone is estimated at 13,550 km², counting the first 10 km of shoreline.

For the Saint John River population, local knowledge suggests the Striped Bass spawned in several locations, e.g., Belleisle Bay and Grand Lake, but the main spawning site is believed to be at the head of tide in the vicinity just downstream of the Mactaquac Dam and Fredericton, NB (Canadian Rivers Institute, 2011). Since 1967, however, spawning has been confirmed only once, Belleisle Bay, 1979 (Douglas *et al.* 2003).

The extent of occurrence for the three populations of Striped Bass in the Bay of Fundy DU overlaps (DFO 2011) and is considered to correspond to the Bay of Fundy (Bradford *et al.* 2012). The Bay of Fundy has an area of approximately 14,500 km². The area located within 10 km of the continental shelf represents approximately 60% of the available aquatic habitat in the Bay of Fundy (9,000 km²).

The total EO for all populations is estimated as 22,550 km^2 and the IAO is estimated as < 100 km^2 (Stewiacke River spawning ground for the Shubenacadie population). The number of locations is considered to be one as there is only one known spawning locality in the Shubenacadie River system where local habitat perturbations, by-catch, directed fisheries, and poaching are the greatest threats. The presence of a spawning population in the Saint John River is not well established enough to justify the recognition of a second location (e.g., no eggs or young-of-the-year have been found since 1979 with sporadic surveys occurring as recently as 2009, Bradford *et al.* 2012).

St. Lawrence River DU

The section of river historically used by St. Lawrence River Striped Bass is the 300-km stretch between Lake Saint-Pierre and Baie Saint-Paul on the north shore or L'Isle Verte (Île Verte) on the south shore. Historically, from July to October, mature Striped Bass from the extirpated population were found on shoals, around islands, islets and reefs and in shallow waters along the south shore and north shore, Île d'Orléans and from Côte-de-Beaupré to Cap-Tourmente (Robitaille 2001).

According to the catches and observations compiled on the newly-introduced population of Striped Bass, the same sector of the St. Lawrence River is considered to be used (Pelletier *et al.* 2010, 2011). Indeed, since its introduction in 2002, Striped Bass have been captured in an area located between east Montreal Island and Rimouski (Ste. Luce), but a great majority (98%) of the catches and observations were made between Lake Saint-Pierre and Rivière-du-Loup on the south shore of the St. Lawrence River (DFO 2010a; A.M. Pelletier, MRNF, pers. comm. April 2012). Striped Bass have also been caught on the North Shore of the St. Lawrence (Côte-Nord Region; N = 2) and in the Saguenay fjord (N = 10). Striped Bass (N = 2 tagged specimens) were caught by sportfishing immediately downstream the Saint-Ours Dam (Richelieu River) in June 2004. In 2012, a specimen was caught in a gillnet installed in the first basin of the Vianney-Legendre fishway (Saint-Ours Dam) in June during the activities of the artificial spawning of the Copper Redhorse (N. Vachon, MRNF, pers. comm., 2012).

In the fall, confinement of juveniles (0+) is observed in Anse Sainte-Anne near La Pocatière, covering an area of 146.3 km² (Pelletier *et al.* 2010). This area is now recognized as a critical habitat under SARA (Robitaille *et al.* 2011). Judging from catch data for the extirpated population and habitat characteristics in Anse Sainte-Anne, the potential spring and summer habitat of juveniles is currently estimated to be a 940-km² zone extending from Neuville and Rivière-Ouelle (Pointe-aux-Orignaux).

During the spring and summer seasons of 2011, a monitoring study was conducted on spawning and egg deposition. This study led into the localization and confirmation of the first active spawning ground for the new population of Striped Bass in the St. Lawrence River. This reproduction area corresponds to the mouth of Rivière du Sud basin at Montmagny (Legaut 2012). Preliminary otolith microchemistry work suggests that up to two more spawning areas may exist (I. Gauthier, NRMF, pers. comm., 2012).

Given the recent re-introduction of the Striped Bass in this DU and the limited amount of information on distribution and spawning areas it is premature to calculate an EO or IAO, but they are assumed to be no more than that of the historical population. Recent otolith microchemistry work suggests that young Striped Bass might originate from up to three spawning areas (I. Gauthier, NRMF, pers. comm., 2012), but the number of locations is considered to be one as there is only one confirmed spawning locality in this DU where local habitat perturbations and dispersed fisheries acting to reduce spawning escapement are the biggest threats

HABITAT

Habitat Requirements

Striped Bass use a wide variety of habitats depending on their life cycle stage and the most important habitats include those necessary for spawning, incubation, nursery, rearing, and feeding areas, as well as pre-spawn staging and wintering areas (DFO 2006). Spawning areas have been located in the Northwest Miramichi River for the southern Gulf of St. Lawrence DU, in the Shubenacadie River, Saint John River (historically), and Annapolis River (historically) for the Bay of Fundy DU (Jessop 1990, 1991; Melvin 1991; Dudley and Black 1978; Van den Avyle and Maynard 1994), and in 2011, in the St. Lawrence River for the newly introduced St. Lawrence River DU (Rivière-du-Sud basin at Montmagny) (Legault 2012).

In most Striped Bass populations, spawning, incubation and early larval development occur in fresh or slightly brackish waters. The Shubenacadie River population, however, spawns in a section of its major tributary, the Stewiake River, affected by a tidal bore.[1] The early life stages are considered to be adapted to these conditions and to tolerate greater temperature and salinity variations than other American Striped Bass populations (Bergey *et al.* 2003; Cook 2003; Cook *et al.* 2006; 2010). Because immature Striped Bass are able to tolerate a broader range of physical and chemical conditions than larvae or young-of-the-year (YOY) (Bain and Bain 1982; Bogdanov *et al.* 1967, cited in Pelletier *et al.* 2010), they are able to colonize a variety of habitats characterized by larger variations in water temperature, dissolved oxygen, salinity and current velocity (Pelletier *et al.* 2010).

At the juvenile and adult stages, Striped Bass use coastal and estuarine habitats (Bain and Bain 1982) and saltwater systems (COSEWIC 2004). The use of eelgrass (*Zostera marina*) beds by the Striped Bass in estuaries is reported by many studies (Joseph *et al.* 2006; Bologna 2007; Weldon *et al.* 2007, 2009; Klassen 2010). Eelgrass plays an important role for several species of fish at different stages of their life cycle, including the Striped Bass for rearing, feeding and sheltering. Striped Bass YOY have been caught in beach seining monitoring program conducted in eelgrass habitat by DFO and community groups in the rivers along the Northumberland Strait (CAMP program; Weldon *et al.* 2007, 2008). In the Miramichi alone, 2,277 YOY striped bass were caught mostly in August all in locations with submerged eelgrass beds (Weldon *et al.* 2008). The Estuarine Index of Biotic Integrity (IBI) program in Kouchibouguac National Park has detected YOY as well in eelgrass habitat since 1997 (Klassen, 2010).

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[1] Bore: Large, often breaking, wave that is formed when the incoming tide travels against the current of a river in some funnel-shaped estuaries or bays.

Young and adult Striped Bass populations undertake a fall migration to estuaries or freshwater habitats to overwinter (*see* **Dispersal and Migration** section). This behaviour is considered to enable them to avoid the low winter ocean temperatures (*see* **Biology** section). Wintering and spawning sites do not necessarily overlap in distribution or occur in the same drainage (DFO 2006). On the basis of an analysis of the calcium/strontium ratio of otoliths of Striped Bass from the Shubenacadie River population, Gemperline *et al.* (2002, cited in Bradford and LeBlanc 2011) demonstrated that Striped Bass can overwinter in different habitats (freshwater, estuaries, marine) over the course of their life cycle.

After the wintering period (December to March), Striped Bass move into the estuaries following ice melt in the spring. For the Southern Gulf of St. Lawrence DU, the confluence of the Southwest and Northwest Miramichi rivers (Beaubears Island) has been identified as a spring staging area for pre-spawning Striped Bass (Douglas *et al.* 2009). A distance of 15 to 18 km separates the staging area from the spawning site (Douglas *et al.* 2009). For the Shubenacadie River population (Bay of Fundy DU), the pre-spawning staging area is at the confluence with the Stewiacke River. These pre-spawn staging areas could be essential to gonad maturation or could be characterized by environmental conditions favourable to spawning (Bradford and LeBlanc 2011). For the St. Lawrence River DU, no pre-spawning area is identified yet besides the spawning area in the mouth of the Rivière du Sud basin at Montmagny, where the river discharges a great proportion of freshwater at this time in the spring (Legault 2012).

Habitat Trends

Because juvenile and immature Striped Bass feed along the shores of the St. Lawrence River (Robichaud-LeBlanc *et al.* 1997), shorelines are important habitat (Robitaille 2010). In Canada, the St. Lawrence River system is a major waterway that has been considerably modified over time for commercial navigation. Since the major capital dredging operations were completed, an average maintenance dredging of 519,250 m^3 per year has been required throughout the fluvial zone, estuary, and Gulf of St. Lawrence (Villeneuve and Quilliam 2000, cited in Hatin *et al.* 2007).

Eelgrass, which has been widely recognized as an important component of coastal ecosystems in eastern Canada and a primary habitat for many species, including the Striped Bass (Joseph *et al.* 2006; Bologna 2007; Weldon *et al.* 2007, 2009; Klassen 2010; Côté 2012), is considered in decline owing to eutrophication, disturbance by green crab, and environmental changes (Hanson 2004). Protocols for restoring eelgrass beds by replanting root stock have been tested in Newfoundland and hold promise for future management action.

Southern Gulf of St. Lawrence DU

There is very little that is specific to Striped Bass habitat in the southern Gulf of St. Lawrence, however, habitat loss or degradation does not appear to be an issue for the Southern Gulf of St. Lawrence DU, and the closure of the pulp mill in the Miramichi River may actually represent an improvement in habitat quality (DFO 2011). Over the years, the spawning habitat in the Northwest Miramichi River was studied in terms of distribution, temperature and salinity (Robichaud-LeBlanc *et al.* 1997), Robinson (2000) reported early life history movements, and Douglas *et al.* (2009), prespawning, spawning, and post-spawning behaviour (Douglas *et al.* 2009). Beach seining work shows that YOY movement throughout the southern Gulf of St. Lawrence implies the use of a multitude of different habitats (Douglas and Chaput 2011a), and the acoustic work completed in the Miramichi River and the southern Gulf of St. Lawrence shows location and behaviour related to temperature (Douglas *et al.* 2003). In the Kouchibouguac National Park, winter distribution and behavior were established in relation to temperature and salinity (Bradford *et al.* 1997a) (see **Biology**).

Bay of Fundy DU

Striped Bass spawning ground in the Annapolis River is considered to have been affected by changes in the quality or physical and chemical properties of the water; these changes in turn are associated with changes in flow patterns caused by the construction of a causeway and the Annapolis Tidal Station (see **Threats and Limiting Factors**). On the Annapolis River, the cessation of spawning has also been attributed to inadequate physical and chemical conditions: namely, agricultural pollution or an excessively low pH (Jessop 1995). Recent monitoring of the river's water quality has noted relatively stable conditions over the past 10 years although water temperature has shown a consistent, modest increase (Freeman 2012). In the Saint John River, the construction of the Mactaquac Dam in 1967 is thought to be one cause for the disappearance of Striped Bass spawning ground just downstream of the dam (Douglas *et al.* 2003). Since the 1970's, however, other aspects of water quality have improved (Canadian Rivers Institute 2011).

St. Lawrence River DU

The most important annual dredging operation is the maintenance of a 9.7 km² navigation channel in the vicinity of Île d'Orléans. Since the mid-1800s, hundreds of million of cubic meters of sediment have been dredged in the Québec section of the St. Lawrence River to create navigation channels and harbors (Villeneuve and Quilliam 2000, cited in Hatin *et al.* 2007). The loss or alteration of habitat quality by dredging activities during the construction of the seaway may have contributed to the extirpation of the St. Lawrence River DU. The summer rearing areas of immature bass, located off a number of islands in the St. Lawrence, were modified by the dumping of dredged material (Robitaille 2001), concentrating the Striped Bass in a few spots along the south shore. These areas quickly became very popular fishing sites (Robitaille and Girard 2002). Fish habitat losses between 1945 and 2008 have been estimated at close to 360 ha for the sector between the Québec and Île d'Orléans bridges (Robitaille *et al.* 1988). Since 1975, however, dredging practices, however, have changed and are now carried out exclusively for maintenance and the volumes of dredged sediment are much smaller than they were in past operations, which were designed to expand and deepen the seaway.

Since 2009, habitat near feeding areas used by immature Striped Bass of the extirpated population (south of Île Madame, in the vicinity of Île d'Orléans) is no longer used as a site for the disposal of dredged material (DFO 2010c). In addition, the Canadian Coast Guard is currently exploring ways to reduce the environmental impacts of the maintenance dredging of the St. Lawrence Seaway and the resulting disposal sites (DFO 2006).

BIOLOGY

In Canada, Striped Bass populations are exclusively anadromous. To complete its life cycle, the Striped Bass must therefore move between freshwater spawning habitats and brackish or saltwater feeding areas in estuaries and along coasts.

Life Cycle and Reproduction

Spawning

The Striped Bass migrates upriver in the spring to spawn. The spawning sites are located in freshwater environments subject to tides near the upper limit of the freshwater-saltwater transition zone of estuaries, thus in freshwater or slightly brackish water (Raney 1952). In Canada, because some Striped Bass overwinter in freshwater (Jessop 1980; Hogans 1984; Rulifson and Dadswell 1995), they migrate from freshwater to brackish water in the spring to spawn. A gradual south to north progression in spawning timing is observed in their range (Bradford and LeBlanc 2011).

Spawning is triggered by an increase in water temperatures. Spawning behaviour has been described primarily in American populations, which spawn earlier in the spring, but over an extended period (Pearson 1938; Merriman 1941; Raney 1952; Karas 1974; Setzler *et al.* 1980; Setzler-Hamilton *et al.* 1981; Rulifson *et al.* 1993; Van Den Avyle and Maynard 1994, cited in Douglas *et al.* 2009).

In Canada, Striped Bass spawn in May and June. This period corresponds to the increase in water temperatures above 10°C to 15°C (Robichaud-LeBlanc *et al.* 1997). Spawning can last from two to four weeks (Rulifson and Dadswell 1995; Robichaud-LeBlanc *et al.* 1996; Rulifson and Tull 1999). Spawning occurs close to the surface, frequently at dusk. The milt and eggs are released simultaneously in the water column and disperse freely.

Southern Gulf of St. Lawrence DU

The only confirmed spawning ground for the Southern Gulf of St. Lawrence DU is located in the Northwest Miramichi River. Recent acoustic tracking studies continue to show that spawners show high fidelity to the Northwest Miramichi estuary (Douglas *et al.* 2009). The particular hydrological conditions in this sector are considered to be favourable for egg development and survival (Douglas and Chaput 2011a, b). The spawning chronology is predictable and spawner abundance has been monitored since 1993 (Bradford *et al.* 1995; Bradford and Chaput 1996; 1998; Douglas *et al.* 2001, 2003; 2006, 2009; Douglas and Chaput 2011a,b).

The size and age structure of the population has been consistent over time (Douglas and Chaput 2011a). The dominant age continues to range between 3 (35 and 45 cm) and 5 years (40 and 50 cm). Male Striped Bass generally recruit at age 3, and females at age 4. Although the contribution of Striped Bass aged 5 to 7 years to the spawning stock has improved since 2003, it remains low relative to younger year-classes (Douglas and Chaput 2011b). Some Striped Bass, however, can be reproductively active for 20 years or more (Secor 2000), although they may not spawn each year (Waldman *et al.* 1990).

During the spawning period, there is often a very strong sex bias in favour of males (Doulas *et al.* 2003; Douglas and Chaput 2011b). During 2008 trap-net survey conducted in collaboration with Natua'quanek First Nation, the sex-ratio was 1 female for 4.14 males (Comeau 2008).

In the Northwest Miramichi River, spawning occurs between early and mid-June (Douglas *et al.* 2006). The migration of spawners to the spawning site occurs at the same time as the spawning migration of clupeids, primarily Alewife *(Alosa pseudoharengus)* and Blueback Herring *(Alosa aestivalis)*, which are caught by the gear of commercial fishers in the estuary (Douglas *et al.* 2006; Douglas and Chaput 2011a, b). According to the results of acoustic telemetry tracking conducted in 2004 and 2005, movements of male and female Striped Bass from the staging area to the spawning area occurs at the same time. This is true both for spawners that overwinter in the Miramichi River system and for those that overwinter elsewhere. Increases in temperature rather than the absolute temperature (~10°C) are reported to be the cue initiating the movements of Striped Bass onto the spawning grounds (Secor and Houde 1995; Robichaud-LeBlanc *et al.* 1996; Douglas *et al.* 2009). Both male and female Striped Bass meet at the water's surface and gametes from both sexes are released simultaneously (Douglas and Chaput 2011a). Between 2003 and 2010, acoustic tagging of Striped Bass has demonstrated that they are faithful to their spawning site on the Northwest Miramichi River. The occupation of the spawning grounds is limited to one to two weeks. Females leave the Miramichi River spawning grounds sooner than the males, where the males remain in the estuary for a significantly longer period of time. In 2010, males (N = 10 with acoustic tags) left the estuary on June 1 on average (between May 25 and June 26), whereas females left by May 27 (between May 20 and June 1) (Douglas and Chaput 2011b).

Bay of Fundy DU

The Shubenacadie River, a tidal bore river, continues to be the primary spawning site of the Bay of Fundy DU (Rulifson and Tull 1999). The majority of spawning activity occurs where salinity is low (< 1 to 2 ppt) and where the water temperature is about 15 to 16°C. The combined influence of tidal action and weather results in variable timing of spawning activity (first week of June in 2000 and 2011, and mid-May in 2009 and 2010; Duston 2010; Bradford and Leblanc 2011).

Striped Bass spawning was reported to occur in June in the Saint John River, between Fredericton and Mactaquac, as early as the late 1800s (Cox 1893). Local knowledge suggests that the Striped Bass spawned in several locations, e.g., Belleisle Bay and Grand Lake, but the main spawning site was believed to be at the head of tide in the vicinity of the Mactaquac Dam and Fredericton (Canadian Rivers Institute, 2011).

In the Annapolis River, Nova Scotia, the spawning ground was located approximately 32 to 40 km above the Annapolis River Causeway, as well as in non-tidal portions of the river between Middleton and Bridgetown (Williams *et al.* 1984; Jessop 1990, 1995). At the spawning area the river is 30 m wide and 1.2 to 2.0 m deep; the bottom is sand interspersed between basalt and granite rocks and boulders. Historically, spawning began when water temperatures reach 15°C (Parker and Doe, 1981), usually in late May and early June (Rulifson *et al.* 1987), but there is no evidence of current spawning activity.

St. Lawrence River DU

On the basis of fall upstream movements of large Striped Bass (over 370 mm in total length), biologists studying Striped Bass considered that the now extirpated population spawned in Lake Saint-Pierre (Montpetit 1897; Vladykov 1947; Vladykov and Brousseau 1957; Cuerrier 1962; Magnin and Beaulieu 1967; Robitaille 2010) and that spawning occurred between mid-May and mid-June (Vladykov and Brousseau 1957). In this part of the St. Lawrence River, the water temperature reaches over 15°C around early June (Robitaille 2010), a necessary condition for the initiation of spawning in this species (Raney 1952; Shannon and Smith 1967; Robitaille 2010). Current catch data and otolith microchemistry analysis on Striped Bass from the newly introduced population, however, suggest spawning in areas other than in Lake Saint-Pierre. Since 2003, only 19 observations have been reported in Lake Saint-Pierre (July 2008, June 2009), despite the fact that recreational fishing pressure is relatively high. In contrast, in May 2010, the abundant Striped Bass catches (N =148, 40% with total length > 400 mm; Pelletier 2009) and Striped Bass larval sampling suggest that spawning occurs at Montmagny, Québec. In 2011, spawners (i.e., fish with a total length of > 400 mm, N = 93) were detected by MRNF at the mouth of the Rivière du Sud basin at Montmagny starting from May 23 at a water temperature of 13.2°C. Post-spawners catches indicate that spawning period took place at an average water temperature between 17.6 and 19.0°C (Legault 2012). Striped Bass eggs and larvae were then captured between June 6 and June 16 (Côté 2012). The bathymetric and hydrodynamic characteristics at this area are influenced by the tidal cycles. The range of the mean tide is 4.7 m and isobaths vary from -2.2 to 2.6 m. A predominance of emerged islands is noted on both sides of the spawning area (elevation from 2.0 to 2.6 m), with a main open channel of 1.5 m deep. At this point salinity is low (<0.2 ppt at low tide, and from 0.2 to 2.5 ppt at high tide; Gagnon *et al.* 1993), because the Rivière du Sud discharged a great proportion of freshwater during the spring spawning season. According to a recreational angling survey conducted in May-June 2010 (Beaudry 2010), the Rivière-du-Sud basin at Montmagny would be occupied only during the spawning season. This is supported by acoustic tagging which has indicated that there is a sharp decline of usage of that sector by the Striped Bass from mid-June to October (Bujold and Legault, 2012).

Tagging studies from Ocean Tracking Network (OTN) conducted in the vicinity of Gentilly-2 nuclear power plant has not identified any spawning grounds yet (Bujold and Legault 2012), but this possibility warrants further investigation. There are catches of large fish in advanced stages of maturity (pre-spawn, spawn and post-spawn stages) primarily between March and May in the fluvial zone associated with the thermal plume resulting from warm water discharge from the power plant (Alliance Environement 2005, 2008).

Incubation, rearing and larval development

Striped Bass eggs are green, translucent and semi-pelagic. They are demersal and semibuoyant. By means of the current, fertilized eggs remain in suspension until hatching occurs depending on the water temperatures. Eggs from high physical-energy watersheds are larger and heavier and have smaller surface-to-volume ratios and larger amounts of saturated and monounsaturated fatty acids than eggs from lower-energy watersheds (Bergey *et al.* 2003). According to Pearson (1938), the eggs measure 1.3 mm in diameter when released and fertilized. They swell and harden in the water in about 12 hours, reaching a diameter of 3.4 to 3.8 mm. In 1999, mean egg diameter was 2.57 ± 0.23 mm for the Miramichi River and 3.67 ± 0.10 mm for the Stewiacke River. Eggs from the Stewiacke River are significantly larger than eggs from the Miramichi River (Bergey *et al.* 2003).

According to observations made on the Northwest Miramichi River, hatching takes place two to three days after fertilization, depending on water temperature and environmental conditions (Scott and Scott 1988; Peterson *et al.* 1996; Robichaud-LeBlanc *et al.* 1996). A three-day peak in egg production was observed, with the water temperature fluctuating between 15.6 and 16.6°C. At hatching, the sac fry are 2.0 to 3.7 mm. In the Shubenacadie River population, eggs and larvae are not restricted to the spawning grounds.

Larvae move to the near-shore habitats of estuaries where they grow rapidly. Larval retention zones can be found upstream or downstream from the spawning sites (Robitaille 2010). In a study by Robichaud-LeBlanc *et al.* (1996), the majority of Striped Bass eggs were collected in the freshwater portion of the Miramichi River under tidal influence and they were recovered in low low abundance on the spawning grounds in the Bay of Fundy (Rulifson and Tull 1997, 1999). In the St. Lawrence River, the larvae were found at high concentrations as far as 1.5 km upstream and 6 km downstream of the mouth of the Rivière du Sud, the spawning ground (Côté 2012).

The fry stage lasts between 7 and 10 days, after which the yolk sac is depleted. The larval stage can last between 35 and 50 days, depending on the water temperature and abundance of food. Larval feeding changes as the larvae grow (Humphries and Cumming 1973). In the southern Gulf, young larvae feed on zooplankton (Douglas and Chaput 2011a). Once the larvae exceed 10 mm in total length, their diet gradually shifts from crustacean nauplii to larger zooplankton species or stages (Robichaud-LeBlanc *et al.* 1997).

Vertical larval migrations in the water column, depending on the state of the tide, can enable the larvae to maintain their position in the estuary, and even to move upstream (Setzler-Hamilton *et al.* 1981). Larval distribution is considered to closely coincide with saline fronts in estuaries, which control the distribution and abundance of the prey of the early life stages of bass (North and Houde 2006, North and Houde 2003). In the Miramichi River estuary, the larvae move towards the productive littoral habitats of the estuary, where they grow rapidly until July and where hydraulic conditions are favourable to their survival (Robichaud-LeBlanc *et al.* 1998).

The larval stage ends with metamorphosis into juveniles, at approximately 20 mm, at which point Striped Bass YOY take their adult form (Mansueti 1958).

Young-of-the-year (YOY)

Young-of-the-year Striped Bass are not limited to one particular type of habitat and are not considered to have a preference in terms of salinity or temperature. They progress downstream and into saltwater over the summer, and spread along the coasts. In some areas, the presence of Striped Bass YOY can be associated with the presence of eelgrass beds in coastal estuarine habitat (Joseph *et al.* 2006; Bologna 2007; Weldon *et al.* 2007, 2009; Klassen 2010).

Southern Gulf of St. Lawrence DU

In the southern Gulf of St. Lawrence, first-year nursery areas for young Striped Bass (40 to 200 mm) are found in estuaries and lagoon areas along the coast (Rulifson and Dadswell 1995; Bradford and Chaput 1996; Douglas *et al.* 2003). The confluence of the Southwest and Northwest Miramichi rivers is a nursery area for Striped Bass (Robichaud-LeBlanc *et al.* 1998), with high abundances of age 0+ Striped Bass and the presence of larvae and/or juveniles over an extended time period and through a large range of sizes (Faber 1976). This site is also a nursery area for various other species, including Rainbow Smelt (*Osmerus mordax*), Alewife and Blueback Herring (Locke and Courtenay 1995, cited in Robichaud-LeBlanc *et al.* 1998). In 2011, an intensive beach seine survey in 30 rivers and coastal areas in the southern Gulf of St. Lawrence led to the capture of six YOY (~42 mm) Striped Bass late in the season and it has been suggested that further investigation of potential spawning in the Kouchibouguac River may be warranted (Thistle 2011).

Bay of Fundy DU

Young-of-the-year from the population of the Shubenacadie-Stewiacke system are captured in the lower reaches of the river in early summer, and on the north shore of Cobequid Bay in August and September (Rulifson *et al.* 1987; Douglas *et al.* 2003; Rulifson *et al.* 2008). The intertidal zones of Cobequid Bay have characteristics suitable for nursery sites, i.e., warm water, low salinity and an abundance of prey (Rulifson and McKenna 1987).

St. Lawrence River DU

For the St. Lawrence River newly introduced population, the area of juvenile 0+ (rearing) identified in the Anse Sainte-Anne near La Pocatière in the autumn is now recognized as a critical habitat in the Recovery Strategy (Robitaille *et al.* 2011). This habitat covers an area of 146.3 km² and comprises a 54.6-km² coastal zone (a heterogeneous zone associated with shoals), 67.7 km² of areas 0–2 m, and 24.0 km² of areas 2–5 m. The presence of shoals and strong currents result in changes in the salinity gradient, which increases rapidly from 10 to 18 ppt, and the creation of a thermal front characterized by temperatures of 6 to 7°C downstream from Rivière-Ouelle (Pelletier *et al.* 2010). The coasts in this sector are known to be an important retention area for ichthyoplankton (smelt, herring and capelin larvae) (Dussureault 2009, cited in Pelletier *et al.* 2010).

Growth, Maturation and Fecundity

Robichaud-LeBlanc *et al.* (1998) studied the growth of YOY caught in the Miramichi River estuary in 1992. Growth is relatively slow in the spring (0.32 mm/day in June), fast during the summer (0.75–1.15 mm/day between July and September), slowing down again in the fall (0.17–0.46 mm/day in October and November). In the southern Gulf, YOY can reach over 150 mm after their first growth period (Bradford and Chaput 1996). In October, young Striped Bass generally average 114 mm (87.0 to 147 mm) (Robichaud-LeBlanc *et al.* 1998) and weigh between 10 and 50 g (Bradford *et al.* 1997b).

While experiencing shorter growth seasons, young bass from Canadian populations exhibit a high rate of intrinsic somatic growth relative to American populations (Conover *et al.* 1997, cited in Douglas *et al.* 2003; Robichaud-LeBlanc *et al.* 1998). Thus, with the approach of winter, they are larger in size. These higher growth rates in age 0+ Striped Bass in Canadian populations is considered to improve winter survival, because survival is dependent on size. An important (threshold) size to be reached before winter has been established at between 100 and 110 mm in the southern Gulf (Bernier 1996).

In the Miramichi River estuary, the results of multi-gear surveys (plankton nets, beach seines, and commercial smelt fishing gear) suggest that over early July, young Striped Bass descend to saltwater (Robichaud-LeBlanc *et al.* 1998) and move close to the shores of estuaries in the southern Gulf of St. Lawrence. They occur in large numbers in the sheltered bays of estuaries, where they feed primarily on young invertebrates during their first year (Robichaud-LeBlanc *et al.* 1997). Striped Bass can also be cannibalistic from the onset of first feeding and YOY frequently predate on juvenile shad (R.B. Bradford, DFO, pers. comm. 2011). The wintering sites of the YOY are unknown, but are considered to overlap the wintering sites used by the adults.

As they grow, Striped Bass gradually become high-trophic predators in estuary and coastal ecosystems. Their diet evolves to include not only invertebrates such as crab, but also fish, such as Atlantic Silverside, clupeids (Blueback Herring, American Shad (*Alosa sapidissima*), Alewife), Atlantic Herring, Rainbow Smelt, Atlantic Tomcod (*Microgadus tomcod*) and American Eel (*Anguilla rostrata*) (DFO 2006, 2010a). The increase in Striped Bass abundance on the US Atlantic coast has prompted studies on the impact of this predator on the food chain (Walter *et al.* 2003).

Because the duration of the Striped Bass growth period has a marked effect on size and weight reached at a given age, bass from Canadian populations are smaller than bass from American populations of the same age. According to biological data (size, sex, age) collected under the southern Gulf of St. Lawrence population monitoring program, the maximum fork length of a Striped Bass was 115.5 cm (1993), and the oldest Striped Bass, 15 years (2007) (Douglas and Chaput 2011a). In the St. Lawrence River, the largest Striped Bass captured measured 91.5 cm (total length) and weighed 10.9 kg (Vladykov 1953). In the Bay of Fundy, a bass tagged in fall 1985 in a commercial fish weir in Five Islands (Minas Basin, Nova Scotia) at 3 years old (Rulifson *et al.* 2008) was recaptured in the Shubenacadie River in spring 2010. It was then 104 cm and 28 years old (M. Dadswell, Acadia University, pers. comm. April 2012). In Bras d'Or Lake Cape Breton and in St. Mary's Bay (Nova Scotia), Striped Bass of 26 kg (and 125 cm for St. Mary's) were caught be angling (M. Dadswell, Acadia University, pers. comm. April 2012). Finally, according to Scott and Scott (1988), the Canadian record was caught in Saint John Harbour (New Brunswick) in August 1979: 28.5 lbs and 132 cm of fork length.

The size and age of bass at sexual maturity also varies with latitude (Merriman 1941; Raney 1952; Austin 1980; Setzler *et al.* 1980; Bain and Bain 1982). Initial gonad maturation typically occurs at about 3 or 4 years in males (fork length of 35 to 55 cm). The females reach maturity later, at 4 to 6 years (45–55 cm fork length or over) (Berlinsky *et al.* 1995; Douglas *et al.* 2003; Powles 2003; Douglas and Chaput 2011b). Spawners survive spawning and can spawn again, their successive contributions sometimes alternating with a year of rest. In some rivers, spawning was observed in males to the age of 14 years (Setzler *et al.* 1980), and even over 20 years (Secor 2000). Gonad maturation during the weeks preceding spawning is associated with an increase in water temperature (Secor 2000).

Striped Bass are very fecund (approximately 50,000 eggs per kg of body weight), which offsets the high mortality rate during their first year of life. Northern populations typically have slightly lower fecundity, at a given size, than those in the southern part of the species' range (Olsen and Rulifson 1992). Using a fecundity relationship established by Goodyear (1985) based on age and size composition of southern Gulf of St. Lawrence Striped Bass, Douglas *et al.* (2006) estimated the average fecundity of a 4-year old female (45–55 cm) at 83,000 eggs, and that of a female 10 years and over at 600,000 eggs. These results are comparable to estimates obtained by Hogans and Melvin (1984) on eight females sampled in the Kouchibouguac River, i.e., between 78,000 and 121,000 eggs for sizes between 47.5 and 52.5 cm, and to estimates of fecundity obtained for females in the Shubenacadie-Stewiacke river system (41,000 to 2.1 million eggs for sizes between 44.9 and 91.0 cm (Paramore 1998).

Generation time corresponds to the average age of parents in the population. A 4 year generation time is accepted for the southern Gulf of St. Lawrence and the Bay of Fundy DUs (Douglas and Chaput 2011a; Bradford and LeBlanc 2011; Pelletier *et al.* 2011). For the new population in the St. Lawrence River, actual data suggest a mean age of parents of 3 years old (Pelletier *et al.* 2011). Based on observed resemblances in growth patterns between the source population (Miramichi River) and the new population, however, the generation time considered for the St. Lawrence River DU is also 4 years.

Survival

Most Striped Bass populations are subject to variation in abundance, which is characteristic of fish species in which survival of the initial stages, i.e., eggs and larvae, is a key factor in recruitment (May 1974; Dahlberg 1979). Survival of eggs to hatching is closely tied to the physical and chemical properties of the incubation habitat, particularly temperature and salinity (Cook *et al.* 2010), dissolved oxygen and the presence of a moderate current, which keeps the eggs suspended in the water column (Cooper and Polgar 1981).

The length of the incubation period is dependent on temperature. The highest hatching (87%) and 24-hour larval survival (76%) rates are obtained at 18°C (Morgan *et al.* 1981). At that temperature, hatching occurs approximately 48 hours after fertilization (Pearson 1938; Raney 1952). In American populations, egg survival declines significantly at temperatures over 23°C; it also declines, but gradually, at temperatures below 17°C. Virtually no eggs incubated at temperatures below 12°C survive to hatching (Morgan and Rasin 1973; Rogers *et al.* 1977). The two other factors, namely a sufficient level of dissolved oxygen and the presence of a current, can have a combined effect on egg survival. The eggs generally have a higher density than water and, in the absence of current; they drop to the bottom, where they are more exposed to anoxia (Chittenden 1971; Rawstron *et al.* 1989). The presence of a moderate current creates low turbulence levels, which keeps the eggs in suspension in the water column during incubation.

Survival of the larvae, like the eggs, depends on physical variables, including temperature, dissolved oxygen and salinity. In laboratory testing, Cook *et al.* (2010) studied the survival and growth of early life stages using samples captured in the Shubenacadie River. For average salinity conditions, the optimum temperature for maximum growth in juveniles is considered to be between 26 and 30°C, which is similar to optimum temperatures for American populations. Survival of 1- to 7-day posthatch larvae was 40% at temperatures between 10 and 14°C. Older larvae (23-day posthatch) were less tolerant to cold, with 20% surviving 7 days at 10°C (Cook *et al.* 2010). Survival of eggs and larvae exposed to salinities between 2 and 20 ppt was 60%, whereas it was reduced to less than 50% at salinities of 30 ppt and over (Cook *et al.* 2010). Survival and growth of juveniles (55 to 104 days posthatch) are not compromised if salinity is between 1 and 30 ppt (Cook *et al.* 2010). The eggs, larvae and juveniles of the Shubenacadie River population are considered to have a number of characteristics suggesting local adaptations to a highly dynamic environment (Cook *et al.* 2010).

Upon resorption of the yolk sac and the onset of feeding, the availability of a sufficiently abundant food supply becomes a limiting factor in larval survival (Cooper and Polgar 1981). This key period occurs when the larvae are about 8 days old and measure 6 to 7 mm. In natural environments, the rate of survival of larvae that have exhausted their yolk reserves is directly related to the abundance of zooplankton in their environment (Kernehan *et al.* 1981). The physical condition of the larvae is correlated with the density of copepods and cladocerans in the environment (Miller 1977; Martin *et al.* 1985). Survival rate to the larval stage is considered to be a key factor in year-class strength (Cooper and Polgar 1981; Rago *et al.* 1989), and therefore in adult abundance several years later (Goodyear 1985; Rago *et al.* 1989; Ulanowicz and Polgar 1980).

Starting at the juvenile stage, Striped Bass are better able to tolerate changes in environmental conditions. They can move to estuarine or coastal habitats, often in schools of same-sized fish, to meet their food requirements. Although more tolerant to changes in temperature and salinity than eggs or larvae, the spatial variability encountered in environmental conditions in a single watershed can be a factor influencing Striped Bass growth and survival in their first year of development (Cook *et al.* 2010). Because Canadian populations are at the northern limit of the species' range, the average size reached by Striped Bass age 0+ after their first growth period seems to play a very important role in subsequent recruitment (Bradford *et al.* 1995; Bradford and Chaput 1996; Robichaud-LeBlanc *et al.* 1998). The survival of our northern populations is affected by severe winter weather conditions that cause selective mortality in YOY. Individuals that have failed to reach a important (or threshold) size of at least 10 to 11 cm by the fall will reportedly be less likely survive their first winter than the Striped Bass that have reached a larger size after their first year of growth (Bernier 1996; Bradford and Chaput 1997; Hurst and Conover 1998; S. Douglas, DFO, pers. comm. February 2011). Low water temperature events combined with severe winter conditions may account for the interannual variability observed in Striped Bass recruitment on the Miramichi River (Robichaud-LeBlanc *et al.* 1998). This is all the more plausible in that juveniles and adults are considered to stop feeding when the water temperature falls below 10°C, i.e., in October and November in the southern Gulf of St. Lawrence

(Robichaud-LeBlanc *et al.* 1997). Winter survival therefore depends on stored energy reserves and temperature and salinity conditions for osmoregulation (Hurst and Conover 1998, cited in Douglas *et al.* 2006). The first overwintering period is therefore important for Striped Bass. The causes of mortality include starvation, size-dependent predation and physiological intolerance to reduced temperatures (Sogard 1997, cited in Douglas *et al.* 2006). Moreover, high flow conditions (December to March) can displace juveniles downstream to unfavourable sites. In Miramichi Bay, juveniles could be exposed to lethal temperatures and osmotic stress conditions (Hanson and Courtenay 1995, cited in Douglas *et al.* 2006).

In the adult population structure, dominant year classes occur in years in which spawning took place in favourable conditions (Cooper and Polgar 1981; Goodyear 1985; Douglas *et al.* 2001). A positive correlation exists between the growth of age 0+ Striped Bass and mean water temperature (Setzler-Hamilton *et al.* 1981; Dey 1981; Rogers and Westin 1981; Uphoff 1989; Rutherford and Houde 1995; Secord and Houde 1995; Rutherford *et al.* 1997). Variations in water temperature directly affect juvenile development by altering their metabolic rates or indirectly affecting the availability of food (Robichaud-LeBlanc *et al.* 1998).

In the southern Gulf of St. Lawrence, the nematode *Philometra rubra* is known to occur in Striped Bass (Hogans 1984). It is possible that the survival of Striped Bass infected by this nematode is compromised when subjected to other stresses, such as a viral or bacterial infection or contaminants (pollution) (J. Melendy, DFO, cited in Douglas *et al.* 2006). Lymphocystis is a common chronic infection caused by an irodovirus, leading to hypertrophied cells of the skin and fins. This type of infection is also common in the southern Gulf of St. Lawrence. Between 2001 and 2005, infection rates of 1 to 8% were observed on the Northwest Miramichi River (Douglas *et al.* 2006). In April 2002 and 2004, Gagné *et al.* (2007) reported the first (and only) presence of viral hemorrhagic septicemia virus (VHSV) in Striped Bass captured in New Brunswick (Miramichi River and Bay). Phylogenetic analyses indicate that the infection was caused by the North American strain of VHSV. Massive fish kills caused by the virus have been reported in the Great Lakes (Hope *et al.* 2010).

Physiology and Adaptability

In laboratory tests, Cook *et al.* (2010) studied early stage growth and survival of Striped Bass captured in the Shubenacadie River. The egg and larval survival rates and the juvenile growth rate are lower at salinities of 30 ppt and over (Cook *et al.* 2010).

Cook *et al.* (2006) studied the thermal tolerance of juvenile Striped Bass (19.2 ± 0.2 cm) captured in the egg stage in the Shubenacadie River and acclimated in the laboratory to temperatures of 5 to 30°C. Lethal temperatures (maximum: 24.4 to 33.9°C; minimum: 2.4 to 11.3°C) and maximum important temperature are strongly correlated with acclimation temperature, whereas thermal tolerance is inversely correlated with size. Loss of equilibrium occurred at temperatures of between 27.4 and 37.7°C and spasms at temperatures of between 28.5 and 38.8°C. This Canadian population has a wider thermal tolerance range than American populations. The Striped Bass of this population may show local adaptation to large temperature variations, owing to the 14°C difference encountered in the tidal waters of the river (Cook *et al.* 2006).

In the southern Gulf of St. Lawrence, because young bass (age 0+) are found several hundred km from their natal river (Northwest Miramichi River), Striped Bass appear to be tolerant of salinity gradients during their coastal dispersal. This tolerance seems to be more limited in American populations (Robinson *et al.* 2004).

Given its higher tolerance to environmental conditions, the adult bass can withstand greater variations in salinity, temperature, pH and turbidity than juvenile bass (Talbot 1966; Auld and Schubel 1978; Setzler *et al.* 1980). Striped Bass, however, are thought to be sensitive to river acidity, with a pH of 5.9 or less considered to be lethal (Buckler *et al.* 1987, cited in Douglas *et al.* 2003).

The species is highly fecund, opportunistic in its feeding habits and fast-growing; these characteristics facilitate the rapid increase in its numbers in favourable environments. Adult bass, however, are considered to avoid temperatures over 24°C, which may result in their confinement, on the hottest days of summer, to small refuges in certain reservoirs and estuaries in the United States (Coutant 1985). A similar phenomenon, but at the other end of the range of temperatures tolerated by this species, is considered to explain the river overwintering behaviour typical of Canadian populations. By overwintering in freshwater (rivers, lakes), they avoid the cold ocean waters in winter (Rulifson and Dadswell 1995; Bradford and LeBlanc 2011).

By comparison with adults, Striped Bass eggs and larvae are sensitive to minor changes in environmental variables (Cooper and Polgar 1981). Ambient conditions can therefore have a significant effect on the population dynamics of this species. The abundance of progeny for a given number of spawners can vary from year to year (Merriman 1941; Raney 1952; Koo 1970; Van Winkle *et al.* 1979). The most important factor in year-class strength is considered to be egg and larval survival. The abundance of a year class is reported to be already largely determined at the time of metamorphosis, i.e., at the end of the larval stage (Chadwick *et al.* 1977).

Bass populations are often characterized by variable recruitment (Merriman 1941; Raney 1952; Koo 1970; Van Winkle *et al.* 1979; Setzler *et al.* 1980; Ulanowicz and Polgar 1980; Kernehan *et al.* 1981; Cooper and Polgar 1981; Polgar 1982). Catch data show significant interannual variability; years in which catches are high correspond to

the passage of strong year classes through the exploited segment of the population (Comité aviseur sur la réintroduction du bar rayé 2001). Periodicities of 6, 8 and 20 years have been detected in commercial Striped Bass landings on the Atlantic coast of the US (Van Winkle *et al.* 1979). Some biologists consider that heavy fishing can either cause or amplify variations in the abundance of bass populations (COSEWIC 2004).

Dispersal and Migration

Given its anadromous nature, Striped Bass exhibits a migratory behaviour. It frequently undertakes migrations for various reasons, depending on its life cycle stage. Migrations vary in distance and are associated with fish growth, feeding, reproduction, climate and environmental conditions (DFO 2010c).

By early fall, juvenile and adult Striped Bass return to estuaries or freshwater habitats for overwintering. They cease feeding when water temperatures fall below 10°C (DFO 2011). At that time, the range of Striped Bass can vary from several km to hundreds of km from their natal river.

<u>Southern Gulf of St. Lawrence DU</u>

In the southern Gulf of St. Lawrence, migrations beginning in the spring from the Kouchibouguac River to Miramichi Bay, 50 km north, or to Tabusintac, 125 km north, have been reported (Hogans and Melvin 1984). In late summer, these Striped Bass enter Nepisiguit Bay, in southern Chaleur Bay, where Striped Bass fishing, when permitted, was at its best in September. These individuals belong to the population that spawns in the Miramichi River (Douglas *et al.* 2003).

Movements related to feeding are observed in a number of rivers. On the Miramichi River, bass captured in a trap net at Millbank show three abundance peaks. The largest abundance peak is observed in the spring (May–June) and corresponds to spawning; a second in summer and a third in the fall are considered to correspond to movements for feeding (Chaput and Randall 1990).

In the Miramichi River, after the eggs have hatched and larvae are growing to become YOY, a certain amount of them will spread and migrate from the Miramichi to other estuaries in the region (Kouchibouguac, Kouchibouguacis (St. Louis), Richibucto, Bouctouche, Cocagne Rivers etc. going south, and Tabusintac, Tracadie Rivers, etc. going north. From summer to fall, juvenile and adult bass occupy coastal estuarine habitats. Acoustic remote sensing studies and seine fisheries suggest that tagged Striped Bass remain within 1 km or less of the shoreline. The presence of age 0+ Striped Bass in the open water smelt fishery on the Miramichi River and their absence in beach seines suggest that they migrate to deeper areas of the estuary shortly before fall (Douglas and Chaput 2011a).

Douglas *et al.* (2001) studied the summer coastal distribution of young Striped Bass. The distribution progressed from the Miramichi River system in early summer and, by August, to the coasts of Miscou Island in the north and the Little Bouctouche River in the south. According to studies currently underway by Thériault *et al.* (in prep., cited in Douglas and Chaput 2011a), YOY Striped Bass apparently extend their distribution further south, and are occasionally captured in summer beach seine surveys in Pugwash, Tatamagouche and Pictou (Nova Scotia) and in the commercial fall Rainbow Smelt fishery in Pugwash and Wallace (Nova Scotia).

Early in the fall, Striped Bass enter several estuaries on the New Brunswick coast. The location of the historical catch sites of hoop net fisheries corresponds more or less to the Striped Bass wintering sites in estuaries in the southern Gulf of St. Lawrence. It is possible that most of the estuaries are wintering sites for this population (Douglas and Chaput 2011a).

Striped Bass from the southern Gulf of St. Lawrence and some of Bay of Fundy also migrate upstream to freshwater in the fall. Striped Bass of all ages undertake the migration seemingly to escape the cold marine waters, which would be fatal during winter (Rulifson and Dadswell 1995; Bradford *et al.* 1995; Douglas *et al.* 2003). In the southern Gulf of St. Lawrence, Striped Bass of all sizes enter a number of rivers along the coast in the fall. Lethal low marine water temperatures would be of lesser occurrence in the Bay of Fundy than in the southern Gulf of St. Lawrence. It was long considered that this migration was undertaken by Striped Bass originating in each of these rivers (Hogans and Melvin 1984; Rulifson and Dadswell 1995). It is now known, however, that all of these fish were part of the Miramichi River population (Bradford *et al.* 1995; Robichaud-LeBlanc *et al.* 1996; Douglas *et al.* 2003; Robinson *et al.* 2004).

Young-of-the-year (0+) from the Miramichi River population travel hundreds of km in the coastal waters in their first growth period. This is the case of age 0+ Striped Bass captured in July and August in the estuaries of the Richibucto and Kouchibouguac rivers, which likely belong to the Miramichi River population (Robinson *et al.* 2004). Such great amount of YOY was caught during the summer months in the Gaspereau (Alewife) traps on the Richibucto River in 2008 and 2009 by the Elsipogtog First Nation. Abundance of YOY is going down when the water temperature is decreasing.

In the Kouchibouguac River, adult bass overwinter in deep sections of the river (Hogans and Melvin 1984). Telemetry tracking of bass wintering under the ice was conducted by Parks Canada in collaboration with DFO in the Kouchibouguac River, within the park's boundary, and in the Kouchibouguacis River. Results have shown that Striped Bass move short distances in winter in the Kouchibouguac and Kouchibouguacis rivers (< 1 km) and select areas having an average temperature of at least −0.4°C and salinity between 0 and 15 ppt (Bradford *et al.* 1997a). When the ice melts, Striped Bass migrate downstream to saltwater, where they feed over the summer. Movements along the river and in the estuary are considered to be closely tied to temperature and prey availability. When the ocean water temperature begins to fall, Striped Bass gradually enter the river to spend the winter. Similar results were obtained

from tagged bass from the Miramichi River system, whose wintering sites are located exclusively in the northwest branch of the river (DFO, unpublished, cited in Douglas and Chaput 2011a). Freshwater and offshore habitats are not used to any large extent.

Bay of Fundy DU

In the intertidal shelves of the Bay of Fundy, Striped Bass movements are affected by tides and light (Rulifson *et al.* 2008). With respect to the Bay of Fundy group, the growth areas are primarily known for the young Striped Bass of the population of the Shubenacadie-Stewiacke system. Young-of-the-year are captured in the lower reaches of the river in early summer, and on the north shore of Cobequid Bay in August and September (Rulifson *et al.* 1987; Douglas *et al.* 2003; Rulifson *et al.* 2008). The coastal zones of Cobequid Bay have characteristics suitable for nursery sites, i.e., warm water, low salinity and an abundance of prey (Rulifson and McKenna 1987).

In early spring, some individuals originating in Chesapeake Bay tributaries leave the bay and move northward along the coast to the Bay of Fundy (Melvin 1978, 1991; Waldman *et al.* 1990). These migratory bass are considered to congregate in the eastern part of the Bay of Fundy, along the coast of Nova Scotia, for the first half of the summer, and then in the western part for the latter half (Dadswell *et al.* 1984). Some enter the Saint John River estuary and migrate to the Reversing Falls area, where they remain until the end of summer (Dadswell 1976). In summer, Canadian Bay of Fundy DU mixes with migratory populations from the United States. Several large populations from the eastern seaboard of the US undertake long coastal migrations in the Bay of Fundy. In September, these migrants return south. Rulifson *et al.* (2008) studied Striped Bass movements in the inner Bay of Fundy using bass captured with commercial fishing gear in Minas Basin and Cobequid Bay in 1985 and 1986. Of the 1,431 Striped Bass that were tagged, 19% (N = 272) were recaptured. The average distance moved for Striped Bass recaptured in Minas Basin and the local watersheds was 55 km. The largest distances moved were by fish over 390 mm. Recaptures occurred at 42 sites across Nova Scotia, New Brunswick, Massachusetts, Rhode Island, Connecticut, New Jersey and Virginia. The longest distance moved was 780 km. The fastest travel time was 17.8 km/day by a fish recaptured in Rhode Island 45 days after release (Rulifson *et al.* 2008). Some individuals tagged in the Saint John River have been recaptured along the coasts of Massachusetts, New Jersey, New York, Delaware and Maryland (Melvin 1978).

In late fall, Striped Bass of all sizes and ages (juveniles and ≥ 3+ years) migrate up the Shubenacadie River, a tributary of Minas Basin, to overwinter in Grand Lake. In May and June, Striped Bass that have wintered in Grand Lake descend the Shubenacadie River downstream to Minas Basin in the upper Bay of Fundy to assemble with adults that have migrated from wintering areas elsewhere in the Bay of Fundy, near the confluence of the Stewiacke and Shubenacadie rivers (Bradford and LeBlanc 2011). The majority of spawning activity occurs in the Stewiacke River, a tributary of the Shubenacadie River.

Local migrations of Striped Bass from the Saint John River followed the same general pattern. Before the construction of the Mactaquac Dam (completed in 1967) on the Saint John River, there were reports of upstream migrations by immature Striped Bass, which appeared to be looking for food, to freshwater habitats up to 320 km from the mouth (Jessop 1991).Striped Bass in the Saint John River (which may be vagrants from other spawning populations) overwintered in freshwater, in Belleisle Bay, Washademoak Lake and other deep sectors of the estuary. In May and June, they spawned in tributaries upstream from the tidal influence zone, and subsequently migrated downstream to saltwater to feed for the summer (Dadswell 1976). In the fall, they returned to the river and, as their activity slowed, congregated in deep waters (Melvin 1978). Little data is available on the development and dispersal of early stages of bass in the Annapolis River (Williams *et al.* 1984; Stokesbury 1987). Annapolis River Striped Bass were found primarily in the vicinity of the Annapolis Royal Dam in summer and fall (Jessop and Doubleday 1976). Some individuals from this population migrated upstream to freshwater in the winter. Gill net catches of 4 to 10 Striped Bass per hour were common (Dadswell *et al.* 1984).

St. Lawrence River DU

Movements of Striped Bass from the now extirpated population of St. Lawrence River have been described on the basis of recaptures of tagged fish (Beaulieu 1962; Magnin and Beaulieu 1967; Robitaille 2001). In the fall, an upstream migration of spawners up the St. Lawrence to Lake Saint-Pierre for the overwintering period until spawning was thought to be undertaken because Striped Bass less than 3 years old were not part of this migration (Montpetit 1897; Vladykov 1947; Vladykov and Brousseau 1957; Magnin and Beaulieu 1967). It was then considered that spawning took place in this sector or downstream between mid-May and mid-June. After spawning, fish would migrate downstream to the estuary, where they fed and regained condition during the entire summer. During their growth period (July to October), Striped Bass congregated between Québec and Kamouraska and moved in shallow waters around islands and along coasts (Robitaille 2001). Downstream migration of YOY from the extirpated St. Lawrence River population occurred over several weeks. Catches of juvenile Striped Bass (20 to 35 mm) have been reported near Neuville in early July (Vladykov and Brousseau 1957). In early September, individuals measuring 75 mm could be caught at the mouth of the Ouelle and Saint-Jean-Port-Joli rivers. Young-of-the-year have also been reported in large numbers in fixed gear on the Beaupré coast, north of Île d'Orléans (Vladykov 1945; Trépanier and Robitaille 1995; V.D. Vladykov, unpubl. data; COSEWIC 2004). With the approach of winter, fish aged 1 and 2 years remained in the same area, whereas older fish moved upstream to Lake Saint-Pierre (Robitaille 2001).

Little is known yet on the newly introduced population of the St. Lawrence River, although new information arises from year-to-year since the introduction (Pelletier 2009; Pelletier *et al.* 2010, 2011; Robitaille *et al.* 2011; Legault 2012). Since its introduction in 2002, Striped Bass have been captured between east Montreal Island and Rimouski (Ste. Luce), but a great majority (98 %) of the catches and observations were made between Lake Saint-Pierre and Rivière-du-Loup on the south shore of the St. Lawrence River (DFO 2010a; A.M. Pelletier, MRNF, pers. comm. April 2012). In the spring Striped Bass move to the spawning ground at the mouth of Rivière du Sud basin at Montmagny (Legault 2012). In 2011, spawners were detected in mid-May. Eggs and larvae were captured in June (Côté 2012). According to a recreational angling survey conducted in May-June 2010 (Beaudry 2010), the mouth of the Rivière du Sud seems to be occupied only during the spawning season. This is supported by acoustic tagging which has indicated that there is a sharp decline of usage of that sector by the Striped Bass from mid-June to October (Bujold and Legault, 2012). From 2011 inventory, a larval retention area was identified from June to July around Cap-Saint-Ignace and l'Islet-sur-Mer (Côté 2012). In the fall (September and October), an area with a concentration of YOY was identified in Anse Sainte-Anne near LaPocatière (Robtaille *et al.* 2011). Potential habitat used by juveniles has been suggested to occur between Neuville and Rivière-Ouelle. On the basis of the ecological habitat requirements of juveniles (depth, current, food, etc.), this potential area of habitat is estimated at 940 km², including 320 km of intertidal areas, 250 km² of area between 0–2 m deep and 370 km² of area between 2–5 m deep (Pelletier *et al.* 2010). According to results of seine surveys conducted in 2011, the juveniles Striped Bass concentrate in sea grass beds and in the vicinity of mouth of streams, rivers and springs (Côté 2012). Young-of-the-year of the source population (Miramichi River) also occurs in large numbers in sheltered bays with abundant food sources (Pelletier *et al.* 2010, 2011).

Acoustic tagging studies indicated that 14 large Striped Bass caught in the vicinity of the Gentilly-2 nuclear power plant during the fall 2010 exhibited downstream migration after tagging to Île d'Orléans, La Malbaie-Ouelle, Rivière-Ouelle areas. It has not been investigated if this movement is a reaction post-tagging or if it is a migration to overwintering sites. One Striped Bass has used the discharge canal of the nuclear power plant all winter as an overwintering habitat during the first winter, while the power plant was operational (Bujold and Legault 2012).

Feeding and Interspecific Interactions

Anadromous populations of Striped Bass initially feed primarily on invertebrates and, as they grow larger, on fish (Brousseau 1955; Boynton *et al.* 1981; Rulifson and McKenna 1987; Robichaud-LeBlanc *et al.* 1997; Robitaille 2001). Striped Bass are an important high-order predator in coastal and estuarine zones (Douglas *et al.* 2003). In the St. Lawrence River, Pelletier *et al.* (2010) confirmed that prey size is correlated with the size of Striped Bass. According to stomach content analyses, individuals smaller than 200 mm feed primarily on crustaceans (shrimp of the genus Crangon, other shrimp species, *Gammarus* species, mysids, zooplankton), whereas starting at a size of 200 mm, Striped Bass also feed on fish, although crustaceans continue to be

their primary prey. Starting at a size of 300 mm, fish become the main prey of Striped Bass. Their diet also includes annelids, insects and decaying plant material (Robitaille 2005; Pelletier *et al.* 2010). Sand shrimp (*Crangon septemspinosa*) and marine worms are reported to be the preferred prey of Striped Bass in the Kouchibouguac River estuary (Hogans and Melvin 1984). The fish species found in stomach contents vary depending on location and season. In the St. Lawrence River, the main prey species are Rainbow Smelt, juvenile clupeids, such as American Shad, Alewife, Atlantic Herring (*Clupea harengus*), Flounder (*Pseudopleuronectes americanus* and *Liopsetta putnami*), Atlantic Tomcod, Banded Killifish (*Fundulus diaphanus*), and Threespine Stickleback (*Gasterosteus aculeatus*) (Brousseau 1955; Robitaille 2001; Pelletier *et al.* 2010). In the Kouchibouguac River estuary, the preferred prey are Mummichog (*Fundulus heteroclitus*), juvenile clupeids and Threespine Sticklebacks (Hogans and Melvin 1984).

In American populations, the primary prey reported are Blueback Herring (*Alosa aestivalis*), Atlantic Menhaden (*Brevoortia tyrannus*), Sand Lance (*Ammodytes americanus*) and Bar Anchovy (*Anchoa mitchilli*) (Trent and Hasler 1966; Manooch 1973; Gardinier and Hoff 1982; Dew 1988).

In their feeding and pre-spawn staging areas, Striped Bass move in groups along the coasts, chasing schools of fish, particularly juvenile clupeids (Manooch 1973). In the inner Bay of Fundy, Striped Bass follow the rising tide to feed (Rulifson and McKenna 1987) moving from deep, non-turbid waters to relatively shallow, turbid waters.

POPULATION SIZES AND TRENDS

Southern Gulf of St. Lawrence DU (Northwest Miramichi River)

<u>Historical landings</u>

Commercial Striped Bass catch data from the southern Gulf of St. Lawrence show that the record high (61 t) was reported in 1917 (LeBlanc and Chaput 1991) and that it was followed by a significant decline until 1934. No commercial Striped Bass catches were recorded in the following 33 years (1935 to 1968), which is attributed to the very low abundance during that period (Douglas *et al.* 2003). Commercial catches resumed in 1969, peaking at 48 t in 1981, and then falling once again to less than 1 t in the early 1990s.

Commercial landings between 1969 and 1996 were estimated on the basis of purchase slips and fishery officer reports, two sources known to be incomplete and unreliable (Douglas *et al.* 2003). Work conducted by Fisheries and Oceans Canada on the Miramichi River revealed that actual commercial Striped Bass catches were higher at that location than the volumes reported in fishery statistics (Douglas *et al.* 2003). Commercial catches come primarily from gear designed for Alewife and Blueback Herring or, during the winter, from a fishery directed specifically at Striped Bass (Douglas *et al.* 2003). They were concentrated primarily along the coasts of Kent County, south of Miramichi (regions of Kouchibouguac, Richibucto and Bouctouche). Commercial catches were also reported in other counties of New Brunswick, in Nova Scotia waters bordering the Gulf and in Prince Edward Island, but were much less abundant than in the Miramichi Bay area (LeBlanc and Chaput 1991).

The commercial Striped Bass fishery in the southern Gulf of St. Lawrence was closed in 1996.

Population abundance and mortality

Capture-mark-recapture experiments have been conducted since 1993 in the Northwest Miramichi River to assess the size of the spawning component of the Southern Gulf of St. Lawrence Striped Bass DU (Bradford *et al.* 1995, 2001; Douglas *et al.* 2001; 2006; Douglas and Chaput 2011b; Chaput and Douglas 2011). Striped Bass are captured before the commercial Alewife and Blueback Herring fishery, whereas recaptured Striped Bass are counted during the commercial fishery until the second week of June, when bass leave the Miramichi River system for estuarine and coastal areas. In 2010, spawning took place early in the season, which means that abundance estimates for that year should be considered as a minimum estimate, because a large proportion of the spawning run had already left the system prior to the capture-mark-recapture study. In 2010, catches in trapnets were the highest on record since 1993.

The best abundance estimates are generally obtained using a hierarchical Bayesian model that incorporates both capture-mark-recapture data and the catch from single traps (Chaput and Douglas 2011). According to that model, the number of spawners increased from 3,000 to 5,000 in the late 1990s to annual averages of 35,000 (12,550–92,160) between 2001 and 2010, and 50,000 (16,200–92,160) between 2006 and 2010 (Douglas and Chaput 2011a, b). There has been a striking increase from the low numbers seen in 1996-2000. The number of spawners has returned to those observed in 1994 and 1995. The rate of increase in the last 18 years (1993–2010), about four generations, was 546% (Figure 4). Somewhat more conservatively, there has been about a 91% increase from the average number of spawners over the four year period 1993-1996 (29,375) to the most recent four year period 2007-2010 (56,250, Figure 4).The spawning population of the southern Gulf of St. Lawrence has therefore increased significantly since the introduction of management measures aimed at the recovery of that Striped Bass population. The measures include the closure of directed commercial fishing in 1996 and the closure of recreational and Aboriginal food, social and ceremonial fisheries in 2000 (Douglas and Chaput 2011b).

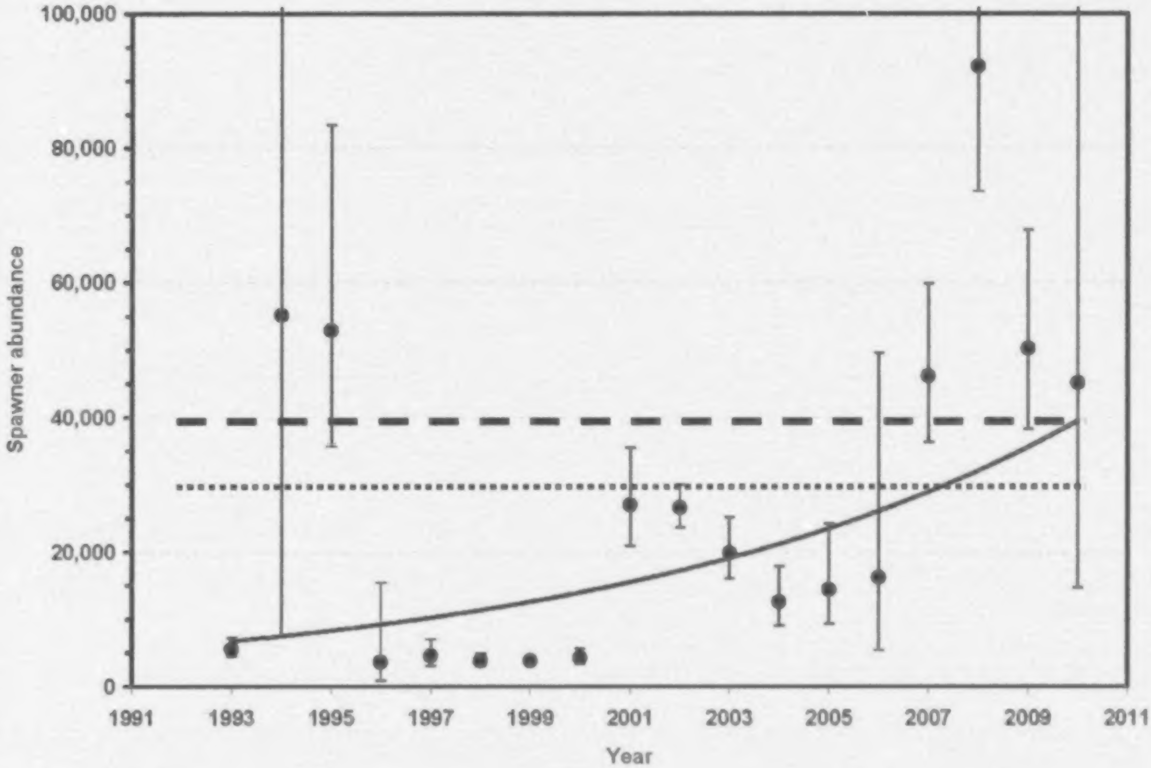


Figure 4. Estimates of Striped Bass spawner abundance (y-axis) derived by applying the Bayesian hierarchical model to capture-mark-recapture data collected in the Northwest Miramichi River system. The dashed line represents the recovery target (31,200 spawners) and the dotted line represents the recovery limit (21,600 spawners). (From Douglas and Chaput 2011b.)

Douglas *et al.* (2006) proposed a recovery limit of 21,600 spawners based on recovery objectives corresponding to the precautionary approach benchmark. A recovery target of 31,200 spawners was proposed based on spawner abundance (50% spawners per recruit). The Seq value (spawners at replacement in the absence of fisheries) was estimated at 63,000 fish. According to Douglas *et al.* (2006), by implementing compliance rules, it would be desirable to reach or exceed the recovery limit (21,600 spawners) in 5 out of any 6 years. Once exceeded, the recovery target (31,200 spawners) should be met in 3 out of 6 years. Spawner abundance levels over the last 6 years (2005–2010) have not been sufficient to meet the recovery target. Although a complete count of spawners in 2010 using capture-mark-recapture techniques was not possible (earlier-than-normal spawning), it was a record year in terms of spawners, and partial estimates from a trapnet are considered sufficient to satisfy the recovery limit of 21,600 spawners (Douglas and Chaput 2011b). Mostly due to the ongoing illegal fishing of adult bass, incidental mortalities in some fisheries, and the by-catch of YOY, total mortality of Striped Bass of the Southern Gulf of St. Lawrence DU remains high. The instantaneous rate of mortality (Z) was calculated from the equation described by Ricker (1975) (Douglas and Chaput 2011b):

, $Z = -Ln\left(\frac{N\,t,i}{N\,t-1,i-1}\right)$, where Ni,t is the abundance of spawners at age i in year t.

The number of spawners at age was calculated using the proportion at age and spawner abundance as estimated by the hierarchal Bayesian model.

Average abundance at age (3 to 9 years old) for Striped Bass year-classes 1997 to 2007 were used to estimate mortality (Chaput and Douglas 2011). Based on the average abundance at ages 3 to 9 years over the period 1997 to 2010, the mortality of adult Striped Bass is in the order of 0.47 (Z = 0.63). These values are marginally lower than the estimates of Z of 0.8–0.9 previously calculated for southern Gulf Striped Bass between the ages of 3 and 7 (Douglas *et al.* 2006). Estimates of total mortality of this population continue to be high compared to mortality from natural causes, which is considered to be low (Douglas and Chaput 2011b). Given that there are no legal retention fisheries that contribute to the mortality of Striped Bass in the southern Gulf of St. Lawrence, illegal fisheries for Striped Bass are considered to contribute significantly to this high rate of mortality (Douglas and Chaput, unpubl. data cited in Douglas and Chaput 2011a; DFO 2011).

Removals for introduction of the St. Lawrence River population

Between 1999 and 2007, approximately 12,000 YOY were removed from the Miramichi River system for stocking into the St. Lawrence River (Douglas and Chaput 2011a).

Bay of Fundy DU (Shubenacadie, Annapolis, Saint John Rivers)

For the Bay of Fundy DU, an increase in abundance since the last assessment was observed in by-catch data from the Shubenacadie River shad fisheries and in recreational angling activity in spring during the pre-spawning period in the Stewiacke River, consistent with expectations arising from recruitment of the 1999 year-class (DFO 2006). The numbers of adults gathering on the spawning grounds are considered by locals to be the highest in living memory (Duston 2010). Of the three historical spawning grounds in the Bay of Fundy DU, the Shubenacadie River is still used for spawning by Striped Bass. This Striped Bass population is the only group from the Bay of Fundy in which YOY bass could recently be sampled (Rulifson *et al.* 1987; Douglas *et al.* 2003). According to the genetic assessment by Bentzen *et al.* (2009) and Bradford *et al.* (2012), a native population in the Saint John River may exist (see also DFO 2011).

The Bay of Fundy is recognized as an area where Canadian Striped Bass populations mix with American populations (Rulifson and Dadswell 1995; Wirgin *et al.* 1995). The Striped Bass frequenting Minas Basin and Cobequid Bay in summer consist of a portion that overwinters in freshwater around the Bay of Fundy and a portion that migrates southward along the eastern US coast (Rulifson *et al.* 2008). Because Striped Bass populations that spawn in tributaries of the Bay of Fundy are mixing with migratory bass originating in US rivers during the summer (DFO 2006), caution is required when estimating the size of actual spawning populations or determining the areas they occupy.

<u>Population abundance and mortality—Shubenacadie population</u>

Only indirect abundance indices were available for Shubenacadie River Striped Bass before 1999. Recreational fishery data suggest that a decline in Striped Bass abundance occurred in the Shubenacadie River between 1950 and 1975, but that numbers remained low and relatively stable through the 1980's (Jessop 1991).

Shubenacadie River YOY Striped Bass have been assessed annually since 1999, except for 2008, via standardized beach seine surveys of the tidal Shubenacadie River and the north shore of the Minas Basin (Bradford and LeBlanc 2011). Results have shown that Shubenacadie River Striped Bass population spawns annually, but that recruitment can be highly variable (Bradford and LeBlanc 2011).

By-catch data from the Shubenacadie River shad fisheries suggest that Striped Bass spawner abundance has increased since 2001, which is consistent with expectations based on recruitment of the 1999 year-class. There is a greater representation of adults over 60 cm (fork length) (Bradford and LeBlanc 2011). Douglas *et al.* (2003) estimated the abundance of Striped Bass of reproductive age (≥ 3+) at 15,000, of which 7,000 were ≥ 4+. Although juveniles have been produced annually since 1999 (DFO 2006), this higher abundance of spawners has not resulted in increased recruitment in the Shubenacadie River. There is a clear variation in year-class strength. Spawning success and/or survival of early life stages (eggs, larvae) during the first growth period are sensitive to climate variability (Ulanowicz and Polgar 1980; Rutherford and Houde 1995; Rutherford *et al.* 1997, cited in Bradford and LeBlanc 2011).

In the Stewiacke-Shubenacadie rivers angler surveys indicated that 1,801 bass (2.2 bass landed per hour fishing effort) was collected mostly from tidal section of the Stewiacke River when adults were gathering on the spawning grounds (April 26-June 20; Duston, 2010). Duston (2010) reported an egg abundance exceeding 1000 eggs/m^3 after an intensive spawning.period (2010).

Historical landings—Annapolis River Population

Surveys of recreational Striped Bass fishers in the Annapolis River suggest that this population declined significantly from 1975-2000 as suggested by declines in catch-per-unit-effort (Jessop and Doubleday 1976; Dadswell *et al.* 1984, Figure 5). The data collected also showed changes in the characteristics of the fish caught, indicating very low recruitment; an increase was observed in average length, weight and age, combined with a sharp decline in the proportion of young fish (Jessop and Vithayasai 1979; Williams *et al.* 1984; Parker and Doe 1981; Jessop 1980, 1990, 1991, 1995). Starting in 1975, the majority of bass captured were adults, with juveniles being rare (Dadswell *et al.* 1984; Jessop and Vithayasai 1979; Jessop 1980; Parker and Doe 1981).

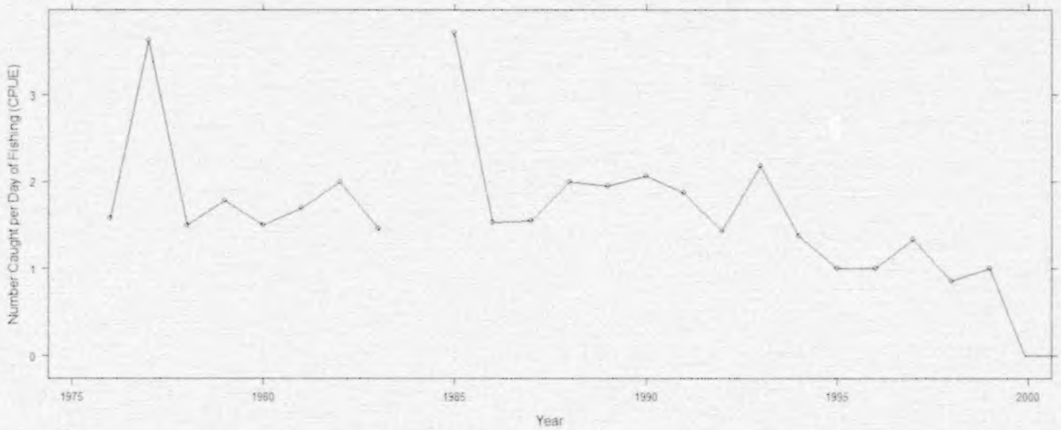
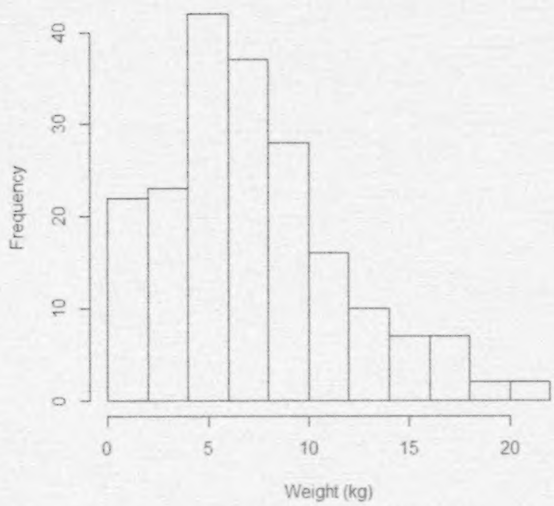
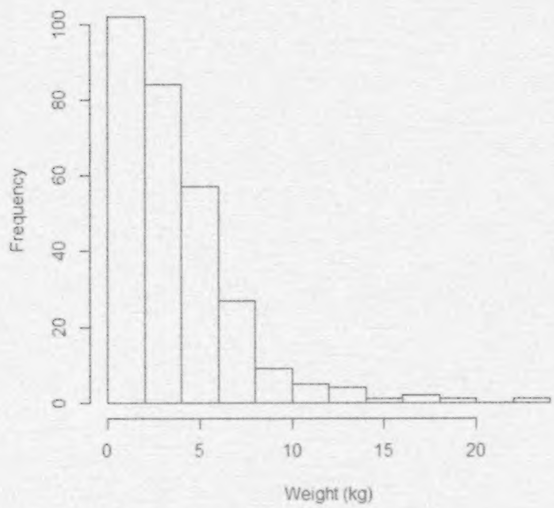


Figure 5. CPUE for Striped Bass in the Annapolis River Basin as determined from select angling records. Break between 1984-1985 indicates no fishing effort due to causeway construction (from McLean and Dadswell, pers. comm. April 2012). Both trends (1975-2000) and (1985-2000) are highly significant (r_s = -0.48, P = 0.018 and r_s = -0.91, P < 0.001, respectively).

McLean and Dadswell (2012) examined angling records for Striped Bass in the Annapolis River. Between 1976 and 2008, bass catches suggested a changing population size structure. During the pre-turbine (Annapolis Tidal Station; 1984) period, bass that were 1.4 – 3.6 times larger bass (7.4 kg mean weight) were caught/day compared to the post-turbine installation population which consisted of fewer large and fishable bass (Figure 6). Angling catches at Annapolis Royal collapsed after 1990. In 2009, Striped Bass angler surveys conducted on the Annapolis River reported 19 captures that had a mean size of 73 cm (10 cm larger than in Shubenacadie and Saint John rivers), but the origin of these fish is unknown (Duston 2010).



A)



B)

Figure 6. Weight-frequency for Striped Bass caught by select anglers in the Annapolis River Basin: **A)** Pre-turbine (1976-1984); and **B)** Post-turbine (1985-2008) (from McLean and Dadswell, pers. comm. April 2012).

Although there is no evidence that new individuals have been produced since 1976 and that recent capture of large Striped Bass is extremely poor, there are still small Striped Bass being caught by anglers (M. Dadswell and T. Avery, Acadia University, pers. comm. April 2012). From the few adult fish caught in the estuary of Annapolis River, these small fish might not be native, but rather summer migrants from the resurgent US populations, and perhaps also from the upper Bay of Fundy (Duston 2010).

Population abundance and mortality—Annapolis River Population

Surveys on spawning activity and juvenile presence of Striped Bass were conducted in the Annapolis River in 1976, 1977, 1980, 1992 and 1994 by means of plankton net tows (Bridgetown area), and seine surveys (estuary of the lower Annapolis River). Based on no catch in 1992 (June) and in 1994 (10 days in early-mid June), Jessop (1995) concluded that data were consistent with a pattern of declining spawning activity and failure of egg survival. Moreover, the increasing proportion of medium-sized and aged fish observed in the mid-1980s and into the 1990s, were associated with the increasing proportions of feeding migrants from other Bay of Fundy and US rivers than to the presence of fish from the Annapolis River population (Jessop 1980; Harris 1988; Harris and Rulifson 1988). It could be argued, however, that capture technique, sampling period and sampling sites may not have coincided with the presence of Striped Bass. Stewart (Nova Scotia Agricultural College, NSAC, pers. comm., 2012) found that if eggs are recently spawned, they can be found, but otherwise, e.g., if it is a day later, they are gone. In terms of sampling effort, a lot of tows have to be performed to efficiently cover the deposition areas.

No Striped Bass (egg, larvae, juvenile, adult) were captured in the Annapolis River or its watershed in the latest beach seine surveys, which were conducted in 2001, 2002 and 2010, or in ichthyoplankton sampling in 2010 (Bradford and LeBlanc 2011). The egg surveys conducted in 2010, however, were only done over one month (June), which corresponds to a sampling period not well suitable to observe signs of spawning activity. Indeed, crews of anglers and fyke netting in the Annapolis River (looking for evidence of bass in the river), reported that large bass are in the river in April and early May (Clean Annapolis River Project (CARP), and T. Avery, pers. comm., Acadia University, April 2012).

Analysis of DNA from adults sampled between 1975 and 1978 (and in the 1990s), however, indicates that these adults were of American origin, except for one individual that could not be associated with a known spawning population (Bradford and LeBlanc 2011).

Historical landings—Saint John River

There has been a Striped Bass fishery in the Saint John River estuary since the early days of European colonization. Recreational angling for Striped Bass in the Saint John River was carried out primarily in summer in the Reversing Falls area, the rocky limit of the estuary. Bass taken at this location are of mixed origin with both American fish and Shubenacadie River fish captured (Bradford and Leblanc 2011). Recreational angler catches showed significant annual fluctuations, coinciding with the abundance indices of migrating American populations (Dadswell *et al.* 1984; Douglas *et al.* 2003). All through the 1990s and at least until 2010, there were plenty of small Striped Bass in the Saint John River estuary. Fishermen and anglers reported large catches of small Striped Bass in the Saint John river estuary after the 1990s and good fishing conditions extending until 2010 (M. Dadswell, Acadia University, pers. comm. April 2012). In 2009,

a single angler reported 80 Striped Bass about 63 cm of fork length caught between June and October mostly around Reversing Falls (Duston, 2010). Striped Bass angling throughout the lower Saint John River has increased in popularity over the last decade further upriver to Fredericton, a distance of approximately 125 km from Reversing Falls (C. Connell, NBDNR, pers. comm., 2012). As for the Annapolis River, catches in the estuary of Saint John River, some might not be native, but rather summer migrants from the resurgent US populations, and perhaps also from the upper Bay of Fundy (Duston 2010).

In contrast, it was assumed that the commercial fishery, which was primarily a winter fishery, targeted primarily the resident Striped Bass population (Dadswell 1976). At the outset, bass was a by-catch of Atlantic Sturgeon fisheries (*Acipenser oxyrinchus*). Striped Bass catches varied depending on the fishing effort directed at sturgeon. A winter Striped Bass fishery began in Belleisle Bay in 1930 (Dadswell *et al.* 1984).

Landing statistics, collected since 1875, show significant fluctuations, with peaks generally being separated by 9- to 11-year intervals (Dadswell *et al.* 1984). In the 1970s, commercial catches declined rapidly. An analysis of catch composition showed the absence of recruitment and confirmed that the population was in decline (Dadswell 1983). The commercial fishery in Belleisle Bay was closed in 1978 (Hooper 1991).

Population abundance and mortality—Saint John River

Eggs were last collected and a young bass (aged 1+) captured in the inner portions of Belleisle Bay in 1979 (Dadswell 1982, cited in Douglas *et al.* 2003).

Systematic surveys conducted in 1992 and 1994 to collect eggs in June and juveniles in August were unsuccessful (Jessop 1995). Additional beach seine surveys in 2000, 2001 and 2009 were also unsuccessful in collecting juveniles (Douglas *et al.* 2003; Bradford and LeBlanc 2011). Given the prolonged absence of evidence of spawning in this river, it was concluded that this population had disappeared (COSEWIC 2004).

Substantial numbers of larger Striped Bass continue to occur in the Saint John River as far upstream as Mactaquac Dam, approximately 150 km from the ocean, but it is uncertain if these fish represent a residual spawning population or vagrants (Bentzen *et al.* 2009; Bradford *et al.* 2012).

St. Lawrence River DU

Historical landings—extirpated population

For the extirpated population, commercial Striped Bass catches were reported since 1920. They show large fluctuations (from 5 to 50 t), with peaks separated by approximately 10 years. Judging from reported commercial landings, the now extirpated St. Lawrence population declined significantly beginning in the mid-1950s. In 1957, annual landings, which had always fluctuated between 5 and 50 t, dropped below 3 t, where they remained until 1965; the last year for which commercial catches of this species were reported. Recreational landings seem to have followed the same trend. The recreational angling fishery was particularly intense around Île d'Orléans and in the Montmagny archipelago during the summer holiday period between mid-July and late September. Downstream from Île d'Orléans, catches were primarily reported in the Montmagny archipelago and along the south shore (DFO 2010a). Striped Bass were also caught by commercial fishers using gear set along the shorelines as far upstream as Lake St. Pierre and significant illegal catches were also reported during winter in Lake St. Pierre. Finally, seiners used to catch this species off several islands in the St. Lawrence River, between Île Madame and Île aux Oies. The last landings of Striped Bass in the Montmagny recreational fishing tournament were in 1963. Occasional catches were landed by recreational anglers until 1968 (Robitaille and Girard 2002). When Striped Bass were present, it was common to catch hundreds of YOY in fixed gear set around Île d'Orléans. This has not been the case since the mid-1960s. It was briefly considered that this population had recovered in about the early 1980s, when some 100 bass were caught in Québec, primarily around the Gaspé Peninsula and in the lower estuary, but these were suggested to be Striped Bass from the Miramichi River (Douglas *et al.* 2003; COSEWIC 2004).

Introduction of the St. Lawrence River population

In 1999, the Ministère des Ressources naturelles et de la Faune du Québec and the Fédération québécoise de la Faune (MRNF) begin the first collections of Striped Bass in the Miramichi River during a feasibility study in order to verify to effectiveness of adequate conditions during transport from Miramichi to the Baldwin-Coaticook Fish Hatchery, the success of culturing them in an artificial environment, and feeding them. The Miramichi River population was selected as the source population for stocking, due to its proximity and its adaptation to northern habitats (Pelletier *et al.* 2011). Meanwhile, a risk analysis (Robitaille 2000) and action plan (Comité aviseur sur la réintroduction du bar rayé 2001) were conducted in order to ensure the monitoring of this new Striped Bass population and its components. Thus, in 2001, an advisory committee on the recovery of the Striped Bass St. Lawrence River DU was established.

A new Striped Bass population appears to be rebuilding in the St. Lawrence River. From first collections in 1999, 11 (age 3, approximately 42 cm) were stocked in 2002, and 16 (age 6) were stocked in 2005 (M. Legault, MRNF, pers. comm. May 2012). In 2002, 11 adults aged approximately 3 years (roughly 42 cm) and 1,050 YOY (approximately 6 cm) from the Miramichi River were stocked in the St. Lawrence River (Pelletier *et al.* 2010). Between 2002 and 2006, 2,000 juvenile bass were captured annually in the Miramichi River in New Brunswick and were transported to a Québec government-operated Baldwin-Coaticook Fish Hatchery to be reared to the spawner stage (sexual maturity). In some years, up-to-half of the YOY collected from the Miramichi River were stocked directly into the St. Lawrence River. By 2002, it was possible to stock some of these surplus fish cultured at Baldwin. In total, between 2002 and 2011, 13,197 juvenile Striped Bass (0+-2+), 965 spawners (3+ to 9+ in age) and over 27.5 million artificially reared larvae measuring 2 to 4 mm were stocked in the St. Lawrence River, between Saint-Pierre-les-Becquets and Rivière-Ouelle (Pelletier 2009; Pelletier *et al.* 2009, 2010, 2011; A.M. Pelletier, MRNF, pers. comm., April 2012). In order to determine the provenance of the individuals caught incidentally (stocked versus natural), juveniles and adults have been marked with microtags (PIT tags) since 2003 and larvae have been marked with oxytetracycline since 2007. A large majority of juvenile fish that have been captured in the system bear no indications of tetracycline marking in the otoliths (e.g., 81.5% of 7,238 age 1+ fish sampled in 2001) which strongly suggests successful spawning of fish stocked into the St. Lawrence River DU (I. Gauthier, NRMF, pers. comm. 2012).

According to Striped Bass captures made from 2003 until 2011, an initial understanding of the biology of the newly introduced population can be inferred (Pelletier 2009; Pelletier *et al.* 2009, 2010, 2011; Belzile *et al.* 2012). In total, 87.6% of the Striped Bass were caught in the Lower St. Lawrence River (Bas Saint-Laurent Region), and 10.3% in the vicinity of Québec City (Capitale-Nationale and Chaudière-Appalaches Regions). Striped Bass were reported from Montreal Region (1 capture) throughout Gaspésie Region (N = 31), including the Saguenay Region as well as three specimens from the Richelieu River, two in June, 2004, and one in June, 2012. (Nathalie Vachon, MRNF, personal communication, 2012). Specimens reported by CDPNQ for the Gaspésie (in Chaleur bay at Gaspé Wharf (Douglas *et al.* 2003; COSEWIC 2004) are thought to be related to individuals from the Miramichi River population and may have originated from that spawning population (V. Bujold, MRNF, pers. comm., April 2012).

<u>Population abundance and mortality—new population</u>

Between 2003 and 2011, the numbers of Striped Bass observed in the system increased, strikingly so for 2011, with an increase of almost 3.5 fold compared to 2010 (Table 2). Given that these introduced fish appear to be successfully reproducing within the historical range of Striped Bass, they were included in the population size estimates and are eligible for assessment purposes as per COSEWIC Guidelines on Manipulated Populations (Appendix E7, Guideline Nos. 3 and 7, COSEWIC 2010a).

Table 2. Number of Striped Bass captured and observed since 2003 following stocking in the St. Lawrence River.

Year	Recaptures			Observations	Total
	Commercial Fishery	Recreational Angling	Experimental Fishery	CDPNQ	
2003	2	1	0	0	3
2004	17	3	7	0	27
2005	29	1	1	0	31
2006	90	0	36	0	126
2007	109	2	19	1	131
2008	145	7	29	30	211
2009	50	6	49	38	143
2010	1420	34	213	13	1,680
2011	5419	60	263	12	5,754
Total	7,281	114	617	94	8,106

Source: Belzile *et al.* (2012)

In 2011, 91% of the catch was composed of YOY and increased markedly from 2010 (Table 3); some 381% (Gagnon and Verreault 2012). Catches occurred between September and October, but most individuals were caught between the second and fourth week of October (Table 3) at fishing sites in Anse Sainte-Anne near La Pocatière (Pelletier *et al.* 2010; Gagnon and Verreault 2012). Historically, young Striped Bass were also sampled in large numbers here in September (Robitaille 2010). Because the St. Lawrence River population was extirpated, the recovery target was defined on the basis of the reestablishment of a viable naturally reproducing population within the same area of occupancy and extent of occurrence as the previous population (DFO 2006). Post-stocking results are encouraging as some introduced Striped Bass have survived, have reproduced and their offspring demonstrate good growth, and tend to occupy a distribution similar to that of the extirpated population (Pelletier *et al.* 2009; 2010, 2011; Legault 2012). A first critical habitat area for rearing at Anse Sainte-Anne has been identified (Robitaille *et al.* 2011), and the mouth of the Rivière du Sud is a confirmed spawning ground when eggs were sampled in 2011 (Legaut 2012). Several components, however, are not well understood, such as the location of the remaining most important habitats used during the various life-cycle stages (reproduction, nursery primarily upstream from La Pocatière, growth, winter refuge), survival rates and mortality rates (DFO 2010a), and it has not been yet determined if the future spawner biomass will be sufficiently high to sustain production over many generations. On the basis of estimates of natural mortality, Z (-0.8), the number of stocked fish that contributed to spawning in 2010 was estimated at between 1,000 and 1,500 spawners (G. Verreault, MRNF, pers. comm. February 2011). A number of measures will need to be maintained or implemented to ensure the success of this stocking program including: 1) continuing Striped Bass introductions to increase their number in the St. Lawrence River; 2) continued monitoring of the newly introduced population in order to observe changes in biological characteristics and population dynamics; 3) monitoring the status of other species that interact with Striped Bass as prey or competitors; and 4) locating and characterizing important Striped Bass habitat, namely spawning, incubation and juvenile growth sites, in order to protect them (Pelletier *et al.* 2011).

Table 3. Weekly captures of young-of-the-year Striped Bass from 2005 to 2011 in the St. Lawrence River.

Month	Week	2005	2006	2007	2008	2009	2010	2011	Total	%
September	1					2	5	15	22	0.32
	2					2	135	12	149	2.16
	3		1	8	2	5	7	79	102	1.48
	4			6	3		17	32	58	0.84
	5	1	1			4	48	141	195	2.83
Total Sept		1	2	14	5	13	212	279	526	7.62
October	1	1		1	7	2	78	75	164	2.38
	2		17		11	2	103	298	431	6.25
	3	1	10	4	14	2	107	144	282	4.09
	4		43	33	2	1	75	191	345	5
	5		5	2			11	3	21	0.3
Total Oct.		2	75	40	34	7	374	711	1243	18
Field							837	4295	5132	74.4
Total		3	77	54	39	20	1423	5285	6901	100

Sources: Pelletier *et al.* (2010), Gagnon and Verreault (2012).

Growth, sex ratio, age and size of spawners—introduced population

Between 2004 and 2009, data were collected on 670 Striped Bass, 507 of which were recaptured by commercial fishers or by MRNF surveys, and kept for laboratory analysis of biological characteristics. The data show the presence of natural reproduction of Striped Bass forming the new introduced population in the estuary. Indeed, although no Striped Bass 0+ were stocked in 2008, 38 juvenile (0+) Striped Bass were reported that year. In 2009, catches of 12 Striped Bass aged 1 year suggest natural spawning success in the new population.

These Striped Bass show a size interval of between 30 and 710 mm and an age structure between 0 and 6 years. Of these individuals, 193 Striped Bass were YOY (average size = 141.5 ± 27.3 mm), and 77% of the Striped Bass captured were less than 2 years old. However, abundance peaks were noted for length classes between 90 and 150 mm, between 210 and 260 mm and between 380 and 450 mm (Pelletier *et al.* 2011). Historically, significant abundance peaks were recorded in the size classes around 250 and 420 mm (Beaulieu 1985). In 2011, 84 spawners were samples and 93% had a length of greater than 400 mm (M. Legault, MRNF, pers. comm., 2012).

The stages of maturity were assessed on the basis of the gonado-somatic ratio and Buckmann's chart (1929, cited in Pelletier *et al.* 2011). For individuals whose sex was determined, the sex ratio (male: female) was 1:0.8 (2 years), 1:2.0 (3 years) and 1:1.4 (4 years). Of these individuals, 62 males and 69 females were considered mature. The analysis of gonad development suggests that, starting at a size of 400 mm, over 50% of the males are mature, whereas in females, the figure is 450 mm. The average age (2.8 years) and average size of mature males (471.9 mm) differ significantly from those of the females (3.2 years and 531.4 mm), with males reaching sexual maturity before the females. The spawners of the new population reach sexual maturity likely earlier than the extirpated population and also earlier than other Canadian populations.

In the estuary, initial maturation does not occur before 3 years of age in males, at a length of 300 mm, and at about 4 or 5 years of age in females, at a size of 400 mm, like in individuals from the Miramichi River population (Hogans and Melvin 1984; Beaulieu 1985; Douglas *et al.* 2003, 2006).

Early maturation of the individuals forming the new St. Lawrence population in late 2000 is likely related to the high somatic growth rate of the population associated with the low density of individuals. The gonado-somatic ratios ranged from 0.04 to 14.4% in males and from 0.20 to 8.7% in females. These values are higher than those of the extirpated population based on the females captured in Lake Saint-Pierre in April 1946, which showed few values over 2% in the pre-reproductive period.

The rate of growth in length was estimated from the back-calculation of scales (N = 181; 1 to 6 years). The back-calculations were also performed on the scales of the extirpated population (1944 –1956; N = 82; 1 to 8 years). Lee's phenomenon (underestimation of size of younger age classes) was not observed in the back-calculated data. The observed and predicted sizes for a given year-class were not significantly different ($p > 0.05$). This means that the growth rate estimates derived from back-calculated lengths at age would not be biased by the existence of selective mortality as a function of fish size. The results show that the mean size of Striped Bass captured between 2004 and 2009 are greater for a given age than the mean size of the extirpated population ($p < 0.05$). The mean growth rate of the newly introduced Striped Bass were no different from that of bass from the Miramichi River source population, as estimated from samples captured between 1994 and 2005 ($p > 0.05$). Studies conducted on the extirpated population showed that Striped Bass were smaller at a given age compared to bass from more southern populations, the latter benefiting from a longer growth period (Magnin and Beaulieu 1967; Vladykov and Brousseau 1957; Douglas *et al.* 2006; Scruggs 1957). According to the analyses conducted on introduced Striped Bass, however, this difference no longer holds (Pelletier *et al.* 2011).

These results suggest that: 1) the carrying capacity of the habitat of the newly introduced Striped Bass is not yet limiting; it provided a variety of food resources and abundant, diversified habitat at the time of the study and 2) St. Lawrence Striped Bass exhibit the same growth properties as their source population from the Miramichi River (Pelletier *et al.* 2011).

The growth patterns of the extirpated and newly introduced populations are comparable in the sense that young Striped Bass born in the spring double in size between the summer and fall. The largest length growth rate occurred between 1 and 2 years, and is considered to decline after 3 years. After 3 years, the slowdown in the growth rate is considered to likely correspond to the period of sexual maturity both in the extirpated population (Magnin and Beaulin 1967) and the introduced population, with the maturation age averaging 2.8 years in males and 3.2 years in females (Pelletier *et al.* 2011). This may be explained by the allocation of energy resources toward gonad development rather than somatic growth (Tremblay 2004, 2009).

Rescue Effect

In Canada, Striped Bass is a migratory fish that disperses from its spawning site for various reasons, including feeding and wintering. According to the latest genetic assessment, the Miramichi River population (southern Gulf of St. Lawrence DU) is clearly genetically and geographically isolated from the other populations (Bradford *et al.* 2012). Rescue from the St. Lawrence River (DU) would be unlikely even if Striped Bass carrying dorsal tags applied in the Miramichi River have been recaptured along the Gaspé coast and are still frequently catch in the Chaleur Bay area. Between the last record of mature Striped Bass in the St. Lawrence River (1968) and the initiation of population supplementation program (2002), Striped Bass were still collected in the Chaleur Bay, and did not rescue the population before artificial stocking was initiated.

Striped Bass from the United States that migrate into the Bay of Fundy to feed use the same areas of the bay as native Striped Bass (DFO 2006). It is unknown, however, whether these individuals spawn in these habitats, which means that the adaptation of immigrating individuals for purposes of reproduction is uncertain and the contribution of immigrating individuals to the reproductive pool of the population to be recovered is not guaranteed. Individuals belonging to American populations already frequent certain tributaries in the Maritimes. According to Bradford *et al.* (2012), individuals captured in the Saint John River (New Brunswick) show varying proportions of putative native Saint John River fish, Shubenacadie River, and American populations. These frequent incursions, therefore, do not guarantee the degree of adaptation required for all life-cycle activities, the capacity to survive year round in Canada, or the existence of suitable habitat for these populations.

In the US, where Striped Bass populations are larger, it is estimated that overfishing, the elimination and alteration of spawning habitat by dams and changes in flow conditions and pollution can contribute, to varying degrees, to declines in abundance. The effect of fishing on Striped Bass abundance has long been underestimated. For instance, migratory populations from Chesapeake Bay were decimated for two decades (1970 and 1980). Following various fishing moratoria in the 1980s and 1990s (Richards and Rago 1999, cited in Rulifson *et al.* 2008), however, and/or a return of environmental conditions favourable to high reproductive success (Field 1997; Walter *et al.* 2003), American populations rebounded to record levels and they offer some possibility of rescue of Striped Bass in the Bay of Fundy DU.

THREATS AND LIMITING FACTORS

In general, Canadian Striped Bass populations are threatened by overfishing (directed, by-catch, poaching), harmful alteration of habitat quality and habitat loss, the presence of contaminants (agricultural and/or industrial pollution), adverse weather conditions, and the presence of invasive alien species. Because Canadian populations are at the northern limit of the species' range, factors that naturally limit abundance, such as the interannual variability of the recruitment, could be acting. Although most threats are common to all Canadian Striped Bass populations, some limiting factors affect some populations (and DUs) more severely than others.

In the Recovery Potential Assessment (RPA, DFO 2006), potential sources of mortality and aggregate harm and their relative rank effect (qualitative ranks) by activity were considered separately for each DU. Striped Bass mortality arising from anthropogenic activities is considered relative to the recovery target defined for each DU. In Canada, although the number of directed Striped Bass fisheries has been reduced, Striped Bass catches by fishing (directed, by-catch, poaching) continue to be considerable (DFO 2006, 2011). Depending on its intensity, directed fishing and by-catch can limit the number of individuals contributing to the spawning stock of the species and can reduce the likelihood of a spawner participating in spawning more than once (Williamson 1974; Jessop and Doubleday 1976; Hogans and Melvin 1984; Secor 2000). The ability of the population to absorb the effects of irregular recruitment is thus reduced.

Southern Gulf of St. Lawrence DU

Fishing

Poaching and incidental mortalities in some fisheries constitute the most important constraints to the recovery of Striped Bass (DFO 2006, 2011; Douglas *et al.* 2006). Under the Allowable Harm Assessment (AHA, DFO 2011), the total estimated loss of medium and large sized Striped Bass was estimated to be in the range of 60,000 fish per year (Table 4). Nearly 70% of adult Striped Bass losses were estimated to occur in illegal (55%) and recreational (14%) fisheries throughout the southern Gulf of St. Lawrence. The fisheries that occur with gillnets have the highest mortality rates on Striped Bass (DFO 2011).

Table 4. Summary of estimated annual losses of medium and large-sized Striped Bass from by-catch in fisheries for other species within the southern Gulf of St. Lawrence. All values have been rounded to the nearest 100.

Fishery	Released	Dead	Handled	Percentage killed (%)	Percentage of total killed (%)
Atlantic Silverside	400	0	400	0.0	0.0
American Eel	15,500	1,300	16,800	7.7	2.1
FSC Atlantic Salmon	1,200	1,900	3,100	61.3	3.1
American Shad	500	2,500	3,000	83.3	4.1
Rainbow Smelt	12,9000	3,900	16,800	23.2	6.3
Atlantic Herring	2,300	4,500	6,800	66.2	7.3
Gaspereau	37,900	4,800	42,700	11.2	7.8
Recreational legal	19,600	8,900	28,500	31.2	14.4
Illegal	0	33,900	33,900	100.0	54.9
Total	90,300	61,700	152,000	40.6	

Source: DFO (2011)

With the introduction of management measures in the Southern Gulf of St. Lawrence DU, such as the closure of the directed commercial fishery in 1996 and the closure of recreational and Aboriginal food, social and ceremonial fisheries in 2000 (Douglas and Chaput 2011b), spawner abundance has increased (Douglas and Chaput 2011b).

Illegal fishing (poaching)

In the southern Gulf of St. Lawrence, illegal fishing activities are recognized as the most severe limiting factor for Striped Bass, and have the greatest contribution to the estimated total adult losses of Striped Bass, accounting for over 50% (Table 4; DFO 2011). All (100%) of the Striped Bass captures in the illegal fisheries are considered to be dead (Table 4; DFO 2011).

Striped Bass are targeted illegally under the guise of angling for Brook Trout (*Salvelinus fontinalis*) in estuaries, Atlantic Mackerel (*Scomber scomber*) around wharves, or any other species with an open season along the coasts (Douglas and Chaput 2011a). However, estimating Striped Bass mortality by illegal fishing is difficult (Trépanier and Robitaille 1995; Douglas and Chaput 2011a). The number of charges laid for offences dealing with Striped Bass has been relatively constant over the last decade. Moreover, for most species, fishing permits are not required to angle in waters under tidal influence (Douglas and Chaput 2011a). Areas where angling effort continues to be high include the Miramichi River system (particularly at Strawberry Marsh), the confluence of the Southwest and Northwest Miramichi rivers (May-June), the estuaries and coastal areas of Tracadie, Tabusintac, Kouchibouguac and Richibucto in New Brunswick and similarly in Nova Scotia's Pictou and Inverness counties (Douglas and Chaput 2011a). Illegal fishing is also reported (E. Tremblay, Parks Canada, pers. comm. April 2012) in the Kouchibouguacis River. Illegal gillnetting is also common in the southern Gulf of St. Lawrence. Large catches occur in the spring and summer along coastal shores, and under the ice on Striped Bass wintering grounds in the Richibucto River (Douglas and Chaput 2011a).

Anecdotal accounts of illegal fishing under the ice have been reported by residents along the east coast of New Brunswick. In some areas, Striped Bass is reportedly still offered for sale door-to-door (Douglas *et al.* 2003).

By-catch

On the basis that Striped Bass can be captured by any of the gear types used for that species (gillnets, trapnets, fyke nets, box nets or pots, etc.), by-catch has been estimated at between low and high, depending on the fishing sites in the southern Gulf of St. Lawrence (Chiasson *et al.* 2002). For the Southern Gulf of St. Lawrence DU, levels of by-catch in several estuarine fisheries have been inventoried on three occasions (Chiasson *et al.* 2002; DFO 2006, 2011). Over 80% and 65% of Striped Bass handled in the gillnet fisheries for American shad and Atlantic herring respectively, were estimated to have died (Table 4; DFO 2011).

On the Miramichi River, quantitative data on Striped Bass catches in various fisheries come from the annual Striped Bass spawner monitoring program in the Alewife and Blueback Herring fishery in the Northwest Miramichi River (abundance index) and from a specific study on by-catch in the smelt fishery on the Miramichi River (Bradford *et al.* 1997b). Data on landings prior to the closure of the commercial fishery in 1996 indicated that by-catch of Striped Bass in this fishery can be significant (LeBlanc and Chaput 1991). In the smelt fisheries, by-catch is primarily associated with YOY. Significant by-catch of YOY bass occurs in fall and winter Rainbow Smelt fisheries and in eel traps (Bradford *et al.* 1995, 1997b). The only estimate of these catches dates back to 1994 and 1995. In two years of monitoring in box nets, estimates of mortality were considerable: 100,000 (1994) and 400,000 (1995) YOY, and about 1,000 fish age 1 and about 1,000 ≥ age 2 fish (in both years).

In winter, catches must be smaller, but no evaluation has been conducted to date (Douglas and Chaput 2011a). Other Alewife and Blueback Herring fisheries using various types of gear throughout the southern Gulf of St. Lawrence are largely undocumented (Chiasson *et al.* 2002.).

Atlantic Silverside (*Menidia menidia*) fisheries in Prince Edward Island and Nova Scotia are similar to the smelt fisheries, given the small mesh size and wings, which intercept all sizes of Striped Bass. The magnitude of the Striped Bass by-catch in recreational fisheries for Rainbow Smelt using gillnets in Prince Edward Island and for American Eel using pots in the Gulf of Nova Scotia is similar to levels experienced in the commercial fishery for this species using the same gear (Douglas and Chaput 2011a). According to Bradford and Chaput (1998), Striped Bass are also caught in Atlantic Herring fisheries at Escuminac (New Brunswick) in the spring by gillnets set along the shore. Ten gillnets targeting American Shad are set during a four-week period between mid-May and mid-June in the coastal waters between Kouchibouguac and Pointe Sapin (New Brunswick). Because this fishery occurs at the same time Striped Bass are migrating to the Northwest Miramichi River to spawn, the Striped Bass by-catch in this fishery is significant (Douglas and Chaput 2011a). During the 1990s, biologists at Kouchibouguac National Park have been monitoring by-catch in the eel (1992-1996), Gaspereau (1991-1998), and smelt (1994-1998) fisheries in the Kouchibouguac and the Black rivers using respectively eel trap, and box net (Gaspereau, smelt). Although mortalities occurred on 5% of the catch, importance of Striped Bass by-catch is not isolated to the Miramichi River but can be applied to other fishing sites in the southern Gulf of St. Lawrence. Most of Striped Bass were caught in Gaspereau box net in the fall in the Kouchibouguac River (64.7%), and in smelt box net in the fall in the Black River (17.1%).

By-catch of Striped Bass in legal recreational angling fisheries is considered minimal (Douglas and Chaput 2011a). Mortality rates of Striped Bass angled and released varied between 8 and 16% (Diodati and Richards 1996; Millard *et al.* 2005) and is considered to depend on many different factors (Wilde *et al.* 2000). Recreational fishers, however, can still cause disturbance to Striped Bass concentration areas, which could lead to abandonment of preferred habitat (DFO 2010c). In addition, because not all fishers have the same approach or level of experience, the return of Striped Bass by-catch to the water results in some degree of mortality. Diodati and Richards (1996) estimated an average mortality rate of 9% (range 2 to 21%) in Striped Bass hooked and released, depending on the fisher's experience and on the type of lures and bait used.

Aboriginal food, social and ceremonial (FSC) fisheries

There are Aboriginal fisheries that target Alewife, Blueback Herring, Rainbow Smelt, American Eel, Atlantic Silverside, American Shad and Atlantic Herring. Striped Bass mortality in these fisheries is similar to levels in the commercial fisheries (Douglas and Chaput 2011a). About 60% of the Striped Bass captured in FSC fisheries for Atlantic salmon are considered to be dead (Table 4; DFO 2011). Striped Bass catches in Aboriginal food fisheries, however, are not counted and harvest statistics are not known, thus limiting the assessment of population catch levels (Douglas and Chaput 2011a).

Several Aboriginal fisheries for Atlantic Salmon (*Salmo salar*; trap nets, gill nets) also intercept Striped Bass in the fall, when they are returning to overwinter in the Tabusintac, Richibucto and Pictou rivers, and in the spring, as they migrate to the Northwest Miramichi River to spawn. Striped Bass catches from three individual gillnets deployed in the Northwest Miramichi River for a period of 24 hours or less yielded 80, 72, and 22 adult bass in June 2003, May 28, 2008, and June 5, 2009, respectively (Douglas and Chaput 2011a). Since 2008, Aboriginal communities have supported Striped Bass recovery efforts in the DFO Maritimes region and have agreed to certain restrictions (R. Bradford, DFO, pers. comm. February 2011).

Other potential sources of Striped Bass mortality/harm

In the Recovery Potential Assessment (RPA, DFO 2006), other potential sources of Striped Bass mortality/harm were reported for the Southern Gulf of St. Lawrence DU. These are: fisheries impacts on habitat, direct mortality under permit, habitat alteration under permit, ecotourism and recreation, shipping, transport and noise, fisheries on food supplies, aquaculture, and militaries activities (DFO, 2006; Douglas *et al.* 2006). Because no further information has emerged on theses potential sources, they have not been discussed further in the AHA for the Southern Gulf of St. Lawrence DU (DFO 2011).

Although ranked as an uncertain source of mortality in the RPA, the habitat alterations under permit such as discharge of effluents are causing mortality of all life stages (DFO 2006). In the fall and winter, large numbers of Striped Bass are attracted to thermal plumes from power generating stations at Trenton (Nova Scotia), Dalhousie and Belledune (New Brunswick). Striped Bass mortalities in winter and spring have been associated with a loss of thermal refuges and exposure to lethal temperatures near power plants (Douglas *et al.* 2006).

Bay of Fundy DU

Fishing (by-catch and directed)

For the Bay of Fundy DU, the presence of migrant US fish confounds the assessment of status (DFO 2011). In the RPA (DFO 2006), potential sources of mortality and aggregate harm and their relative rank by activity were considered for the Bay of Fundy DU. Fisheries, either directed (recreational, aboriginal) or by-catch are listed as high sources of mortalities (DFO 2006).

The Shubenacadie River Striped Bass population is highly susceptible to recreational directed fishing, and by-catch in commercial Gaspereau, and American Shad fisheries (DFO 2006; Bradford and Leblanc 2011). A resurgence of the Shubenacadie River population, from recorded lows in the 1970's, followed the closure of the commercial fishery and sequential reductions in by-catch tolerances (Bradford and Leblanc 2011). At the same time, however, interest and participation in recreational fishing has increased (Bradford *et al.* 2012). Although 90% of fish are reported to be released, post-release mortality has not been assessed for this DU (Bradford *et al.* 2012). Recreational fishing is also a long-established activity on the Saint John River, but its impacts are unknown (Bradford *et al.* 2012). The Aboriginal (food, social, ceremonial) fishery is ranked as a moderate source of impact on the Shubenacadie River Striped Bass population (DFO 2006).

Although the severity of threats and specific mechanisms contributing to the reported loss of the Annapolis River population, and reduced spawner success in the Saint John River population, are mostly unknown, illegal fishing (poaching), and commercial by-catch are reported as potential sources of low mortality for both populations (DFO 2006).

Large-scale changes to habitat, water quality, dams and turbines

The extent of the distribution of spawning populations along the east coast of North America and the presence of spawning sites within areas characterized by heavy human activity suggest that Striped Bass populations, although reasonably tolerant of small-scale habitat perturbations and impacts on habitat quality, are considered to have been affected primarily by large-scale physical changes, such as those restricting free passage of fish (construction of barriers) and causing notable changes in water quality and harmful alteration or destruction of habitat (Douglas *et al.* 2003; Bradford and LeBlanc 2011). In the Bay of Fundy DU, cessation of spawning on the Annapolis River, and perhaps reduced spawner success on the Saint John River, has been attributed to changes in the physical circulation of the estuary, and in water quality affecting the survival of the eggs and larvae (Jessop 1995; Douglas *et al.* 2003; COSEWIC 2004; Bradford and LeBlanc 2011). There is an association between the decline in the Annapolis River Striped Bass population and the construction of first the Annapolis Royal causeway in the Annapolis River estuary in 1960 (Jessop and Doubleday 1976; Williams 1978; Jessop and Vithayasai 1979; Jessop 1980; Parker and Doe 1981;

Williams *et al.* 1984), and the construction of the Annapolis Tidal Station starting in 1980 (began operation in 1984). Indeed, this section of the estuary is located downstream from the known spawning site on the Annapolis River and its alteration has direct impacts on the quality of this habitat. At ebb tide, the sluice gates are closed and water is released from the river through the power generating turbine. This alters the water levels, tidal range, and periodicity and duration of water flow into and out of the upper estuary (Harris, 1988). These different flow patterns are leading to some uncertainty with respect to the maintenance of eggs in suspension in the water column during incubation. The relationship between the specific gravity and density of Striped Bass eggs is specific to each population and each river (Bergey *et al.* 2003). Consequently, variation in the physical energy and estuarine circulation of the watershed can significantly affect Striped Bass spawning success in the Annapolis River. According to the RPA (DFO 2006), such circulation changes are considered the only potential source of high mortality for the population. Moreover, the presence of turbine has a direct impact on Striped Bass. The Annapolis turbine is a large diameter (7.5 m), tube turbine which operates at low head (2-5.5 m). Studies conducted in 1985 and 1986 included daily surveys for damage or dead fish, collection of naturally passed juvenile fishes downstream of the turbine and experimental passage of sonic-tagged adult fish, and larger fish such as the Striped Bass had generally been injured or killed by mechanical strike (Dadswell and Rulifson 1994). The mean decompression rate which occurs at the Annapolis Tidal Station is calculated to be 2.4 atm/s. A pressure flux of this degree is known to be lethal to many species of fish (Tsvetkov *et al.* 1971; Hoss and Blaxter 1979 both cited in Dadswell and Rulifson 1994). Furthermore, the operation of the tidal plant can result in release of suspended sediment and physical scouring along existing channels and at adjacent shorelines (and acceleration of bank erosion). Although these threats were identified in the past (Tidmarsh 1984), they are assumed to be ongoing.

The agricultural pollution and its impact on water quality of the Annapolis River have been reported as one of the factors affecting Striped Bass survival (Jessop, 1995). Direct studies on the impacts of Annapolis River poor water quality on egg survival, however, are limited. In the early 1980s, wild spawned eggs could be sampled from the Annapolis River but no larvae or juvenile resulted from spawning (Jessop 1991). Moreover, in the Annapolis River, the natural snowmelt cycle is responsible for the decline in pH. Because Striped Bass is sensitive to river acidity, with a water pH of 5.9 or less considered to be lethal (Buckler *et al.* 1987, cited in Douglas *et al.* 2003), and because the spring period corresponds to the start of the spawning season in the Bay of Fundy, then the release of waters of low pH from the hydroelectric reservoirs of streams flowing to the Annapolis River at this time and near and upstream of the spawning site could contribute to reduced spawning success on that river (Douglas *et al.* 2003). In June 2010, however, pH was 6.8 in average during the ichthyoplankton surveys near the historical spawning grounds, and a minimum of 6.4 was recorded in August/September 2010 and 2011 for beach seining all along the river from Bridgetown to downstream of the turbine (T. Avery, Acadia University, pers. comm. April 2012).

In the Saint John River, the construction of the Mactaquac hydroelectric dam in 1967 may have significantly modified the spawning, incubation or larval habitats of the Saint John River population (Dadswell 1976; Dadswell *et al.* 1984; Douglas *et al.* 2003; Jessop 1995). According to local knowledge, the main spawning site is believed to be at the head of tide in the vicinity of the Mactaquac Dam and Fredericton, NB (Canadian Rivers Institute, 2011). According to the RPA (DFO 2006), however, potential sources of mortality attributed to elimination of access to rearing habitat above Mactaquac Dam and potential loss of spawning habitat below Mactaquac Dam are ranked as uncertain. Dadswell (1976) reported that 96% of Striped Bass eggs collected in Belleisle Bay in 1975 had a broken membrane, a phenomenon that could be due to the presence of contaminants or to a sudden change in osmotic conditions.

At the adult stage, Striped Bass is a high trophic-level predator and is therefore highly vulnerable to accumulating contaminants that can accumulate in sediments and in the food chain. Contaminants such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons, pesticides, heavy metals and other chemicals have been shown to reduce Striped Bass egg and larval survival in the laboratory (Korn and Earnest 1974; Bonn *et al.* 1976; Benville and Korn 1977; Durham 1980; Cooper and Polgar 1981; Hall 1991). High levels of PCBs or DDT have been observed in the 1970s on the Saint John River (Jessop 1995), when the Saint John River was heavily impacted by gross levels of nutrient enriching pollution, but are currently reduced (Canadian Rivers Institute 2011). Since the 1970's, however, water quality of the Saint John River has improved (Canadian Rivers Institute 2011). Municipalities and industries have installed wastewater treatment systems. As a result, the river's water typically meets Canada's guidelines for acceptable water quality. Upstream of current Striped Bass distribution, however, some stretches of the river regularly have water quality that is diminished by human activities and developments. Low levels of dissolved oxygen continue to be a problem in these stretches of the river because there is not enough water (Canadian Rivers Institute 2011).

<u>Other potential sources of Striped Bass mortality/harm</u>

Fisheries on forage fishes, aquaculture, fisheries impacts on habitat, and scientific research are also reported as potential sources of mortality in the Bay of Fundy DU (DFO 2006). The presence of the introduced Chain Pickerel (*Esox niger*) in the lower Saint John River (since the late 1800s) and in Shubenacadie-Grand Lake, NS, for several decades, is a potential source of mortality owed to its impact on the predator-prey relationships and competition for habitats in overwintering sites (DFO 2006, 2010a, DFO 2011; Bradford *et al.* 2012).

St. Lawrence River DU

The factors explaining the extirpation of the St. Lawrence River DU remain unknown (COSEWIC 2004). The effects of overfishing may have been exacerbated by the interannual variability of the recruitment and the alteration of habitats used by immature Striped Bass, resulting in increased mortality levels that could not be sustained by the population (Robitaille 2001; Comité aviseur sur la réintroduction du bar rayé 2001).

Some of these threats are still present in the St. Lawrence River and some are being felt in a completely different context given that fishing has been prohibited and with a lower risk level than previously (DFO 2006, 2010a). Currently, threats include habitat degradation (release of dredged material), changes in flow conditions, habitat destruction, interannual variability of the recruitment, and by-catch in commercial fisheries.

<u>By-catch</u>

By-catch of Striped Bass in commercial fisheries for American Eel is significant (COSEWIC 2004). Since the introduction of the new population, juvenile Striped Bass are caught in eel traps (Pelletier *et al.* 2010). In the St. Lawrence River, most by-catches of YOY are made in September and October. Although the fishing effort on American Eel has declined significantly in the St. Lawrence River since the early 1960s, the number of fishers has fallen from approximately 200 to fewer than 50, eel gear continues to be a source of Striped Bass mortality.

To assess the possible impact of Striped Bass by-catch in commercial fisheries on the survival and recovery of the population, the various types of fisheries were analyzed both in freshwater and marine environments, taking account of the terms and conditions of the harvesting plans (DFO 2006, 2010a). According to cross analyses, the use of traps between April 1 and mid-December for several species, including American Eel, with mesh sizes of 3.2 to 5.7 cm, are considered to have a moderate impact on Striped Bass. The use of fyke nets between April 1 and mid-February were found to have little impact on the population (DFO 2010a). Because there are two types of gear that are considered to be more likely to result in by-catch of Striped Bass, i.e., eel traps and fyke nets, mitigation measures have been introduced to reduce their impact on the Striped Bass population (DFO 2010a). In 2009, fishers using fyke nets joined the monitoring network. Their participation will make it possible to more accurately assess probabilities of Striped Bass by-catch (DFO 2010a).

Dredging (Habitat alterations under permit)

In the St. Lawrence River DU, dredging is the most significant habitat threat to Striped Bass, particularly juvenile and immature stages and relates to physical habitat destruction, altered flow regimes and increased turbidity (DFO 2006; Wilbur and Clarke 2001; Robitaille 2010; DFO 2010a,c). The navigable channel must be dredged annually mostly in the vicinity of Île d'Orléans along a 9.7km^2 portion of river to remove accumulated sediments. This work could become more substantial in the event of the development of the St. Lawrence Seaway or following a likely decrease in water levels caused by climate change (Pelletier *et al.* 2010; DFO 2010c). Indeed, climate changes could indirectly increase the frequency and extent of dredging work following a decrease in water levels on the St. Lawrence. Since the mid-1800s, hundreds of millions of cubic metres of sediment have been dredged in the Québec section of the St. Lawrence River to create navigation channels and harbors. Maintenance dredging involves the deposit and release of sediments, but also an increase in the current in the dredged channel, followed by changes in salinity and prey availability (DFO 2010c); the now extirpated Striped Bass population disappeared in the years following the construction of the seaway (1954–1959; Beaulieu 1985). Dredging is considered to have displaced immature Striped Bass into southern parts of the estuary, where commercial fisheries for American Eel were numerous and effective at catching Striped Bass as by-catch. This resulted in a significant decline in the number of immature Striped Bass in the population (DFO 2006).

Since the major capital dredging operations were completed, an average maintenance dredging of 519,250 m^3 per year has been required throughout the fluvial zone, estuary, and Gulf of St. Lawrence (Villeneuve and Quilliam 2000, cited in Hatin *et al.* 2007). Today, annual maintenance dredging is carried out to keep the St. Lawrence Seaway free of sediment. Dredging also occurs around roughly 15 small sites, such as wharves, marinas and other access channels, also require periodic dredging (Plan Saint-Laurent 2012). The management of the threat of dredging and deposition of dredged material, however, is considered to have improved considerably over at least the past 10 years. Dredged material is now deposited in designated areas, chosen according to their dispersion capacity. The Recovery Strategy for the Striped Bass (Robitaille *et al.* 2011) considers the severity of this threat as moderate all the while maintaining a high degree of attention if major work is to be planned over the course of the next few years.

With respect to other activities connected with the disturbance and destruction of habitats that reached significant levels in the 1970's and which today are less prominent, the Recovery Strategy considers this threat as a low level threat.

Other potential sources of Striped Bass mortality/harm

The opening of the St. Lawrence Seaway in 1959 and its subsequent development poses a threat to Striped Bass. With the heavy increase in commercial ship and pleasure boat traffic in the St. Lawrence, there is a greater risk of accidents and spills, which can affect the aquatic environment (Robitaille 2010). In addition, vessels are a source of disturbance for aquatic species, including Striped Bass, which use coastal and riparian habitats. Shipping, transport and noise are, however, ranked as only a potential and low source of mortality (DFO 2006).

During the spawning period, warm water released from the discharge channel of the Gentilly-2 power plant could have an impact on the survival of early life stages if mature Striped Bass captured in the Gentilly sector spawn in the thermal plume (Alliance Environnement 2008; Pelletier *et al.* 2010). Hydro-Québec, however, has announced that it intends to close the plant at the end of 2012 (I. Gauthier, NRMF, pers. comm. 2012). Survival of early life stages (eggs, fry) is closely related to environmental conditions and could therefore be compromised following their dispersal from the warm waters of the thermal plume into the cold waters of the river (normal temperature). For example, the water temperature in the discharge channel is 9 to 13°C higher than the normal river temperature. In the immediate vicinity of the plume, it is 4 to 8°C higher, and in an extended area downstream from the plume, it is 1 to 3°C higher (Alliance Environnement 2005). Between April 1 and June 22, 2007, there was an average temperature difference of 11.4°C between the water in the discharge channel and the river water. The habitat alterations under permit such as discharge of effluents causing mortality of all life stages were, however, ranked as uncertain source of mortality in the RPA (DFO 2006).

PROTECTION, STATUS AND RANKS

Legal Protection and Status

In November 2004 COSEWIC assessed the Southern Gulf of St. Lawrence and Bay of Fundy populations (DUs) as threatened and the St. Lawrence River population (DU) as extirpated (COSEWIC 2004). In November 2012 COSEWIC re-examined and designated the Southern Gulf of St. Lawrence as Special Concern, the Bay of Fundy populations (DUs) and the St. Lawrence River population (DU) as Endangered. Despite the release of two RPAs for the three designatable units (DFO 2006; Douglas *et al.* 2006), only the St. Lawrence River population is currently listed on Schedule 1 of SARA as Extirpated (June 2011).

Striped Bass populations and habitat currently receive protection under the federal *Fisheries Act* and *Canadian Environmental Protection Act, 1999.* Fisheries and Oceans Canada (DFO) regulates issues associated with habitat protection under the provisions of the *Fisheries Act* and the harvest in the Atlantic Provinces. Proposed changes to the *Fisheries Act* (to take effect in 2013) would, however, remove habitat protection for any fish species that was not the focus of a commercial, recreational, or Aboriginal fishery. In Québec, responsibility for regulating harvesting is delegated to the province. In Québec, fish habitat is also protected under Québec's *Environment Quality Act* and the *Act respecting the conservation and development of wildlife.* Sections 128.1 to 128.18 of the latter act govern activities likely to affect the biological, physical or chemical components of fish habitat.

In the DFO Maritimes region there is still a retention of Striped Bass permitted in the drift gillnet and weir fisheries. Besides these permitted fisheries in Bay of Fundy waters, there is no retention of Striped Bass by-catch anywhere else in the Maritimes. In Québec, there are no directed fisheries for Striped Bass, but the species is taken as by-catch in commercial American Eel fisheries in inland waters and along the coasts by gill nets, traps or weirs. Management measures for the recreational fishery, which is regulated under the *Fisheries Act*, include daily catch/bags limits, gear restrictions, minimum size limits and seasonal closures (fishing season). None of these fisheries, however, exists in the southern Gulf of St. Lawrence.

Recreational angling is permitted year round in the tidal waters of the DFO Maritimes Region, with the exception of the interior portion of the Annapolis River estuary, which is closed to Striped Bass fishing between April 1 and June 30. There is a daily bag limit of 1 Striped Bass (between 68 to 150 cm) allowed in Bay of Fundy waters (See Maritime Provinces Fishery Regulations under the *Fisheries Act*). In inland waters, recreational angling is allowed during fixed periods in summer, except in waters that flow into the Gulf of St. Lawrence and Northumberland Strait, where it is prohibited. In Québec, given that Striped Bass is the subject of an important stocking campaign, and except for fishers participating in the monitoring network and holders of wildlife management permits (DFO 2010a), it is mandatory for commercial and recreational anglers to return catches to the water, taking care, if the fish is still alive, to cause as little injury as possible (*Quebec Fishery Regulations, SOR/90-214* of the *Fisheries Act*).

Although the St. Lawrence River Striped Bass DU is designated Extirpated under SARA (June 2011), with the establishment of the new population, a by-catch monitoring network was initiated in 2004 in collaboration with commercial and recreational fishers. Data are collected from three sources: 1) catches reported by commercial fishers; 2) data gathered by the MRNF from fish surveys and; 3) observations of Striped Bass catches by recreational anglers transmitted to CDPNQ. Also, since 2009, commercial fishers in the St. Lawrence River, must release all Striped Bass over 20 cm in total length captured live and keep dead individuals of 20+ cm and all individuals of less than 20 cm (dead or alive), which are mostly YOY.

Non-Legal Status and Ranks

In *Wild Species 2005: The General Status of Species in Canada* website, Striped Bass is ranked as *extirpated* in Québec and *at risk* in New Brunswick, Nova Scotia and Prince Edward Island and Canada overall (Canadian Endangered Species Conservation Council 2006). The global status of Striped Bass was last assessed in September 1996 (NatureServe Explorer 2010). At that time, it was ranked as *secure* globally and in the United States (G5TNR). In Canada, the Gulf of St. Lawrence and Bay of Fundy DUs are *not ranked* (NNR) while the St. Lawrence River DU is ranked as *extirpated* (NX). Striped Bass has no status under Nova Scotia's *Endangered Species Act* (M.F. Elderkin, NS Department of Natural Resources, pers. comm. April 2011) or New Brunswick's *Endangered Species Act* (M. Toner and S. Lusk, New Brunswick Natural Resources, pers. comm., April 2011). It is not listed under Prince Edward Island's *Wildlife Conservation Act* (R. Curley, PEI Department of Environment, Energy and Forestry, pers. comm., April 2011).

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Whelan, Christie. Biologist, Fish Population Science. Fisheries and Oceans Canada.

INFORMATION SOURCES

Alliance Environnement inc. 2005. Effets de l'exploitation de la centrale de Gentilly-2 sur le milieu aquatique: état des connaissances. Étude sectorielle. Report presented to Hydro-Québec Production. 129 p. + appendices.

Alliance Environnement inc. 2008. Modification des installations de stockage des déchets radioactifs et réfection de la centrale nucléaire de Gentilly-2. Suivi télémétrique du bar rayé en période de fraie dans le fleuve Saint-Laurent, secteur de Gentilly. Report presented to Hydro-Québec. 36 p. + appendices.

Auld, A.H., and J.R. Schubel. 1978. Effects of suspended sediment on fish eggs and larvae: a laboratory assessment. Estuarine Coastal Mar. Sci. 6: 153-164.

Austin, H.M. 1980. Biology of adult striped bass, *Morone saxatilis*. Pp. 125-132, in Klepper, H. (ed.). Marine Recreational Fisheries 5/IGFA, NCMC, SFI 1980. Proc. 5th Annual Mar. Recreational Fisheries Symposium Boston, Massachusetts.

Bain, M.B., and J.L. Bain. 1982. Habitat suitability index models: coastal stocks of striped bass. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-82/10.1. 29 p.

Beaudry, S. 2010. Suivi du bar rayé (Morone saxatilis) à l'embouchure de la rivière du Sud dans la baie de Montmagny. Comité des Bassins Versants de la Côte-du-Sud. 22 p.

Beaulieu, G. 1962. Résultats d'étiquetage du bar d'Amérique dans le fleuve Saint-Laurent de 1945 à 1960. Natur. Can. 89(8-9): 217-236.

Beaulieu, H. 1985. Rapport sur la situation du bar rayé (*Morone saxatilis*). Faune et flore à protéger au Québec, Association des biologistes du Québec, Québec, Publication No.7, 53 p.

Belzile, K., G. Verreault, G. Bourget, and M. Legault. 2012. Suivi de la réintroduction du bar rayé (*Morone saxatilis)* dans le Saint-Laurent – Bilan 2011.

Bentzen, P. I.G. Paterson, and R.G. Bradford. 2009. Greater genetic differentiation and complex migratory behavior of striped bass in the Canadian Portion of the species range. p.923. American Fisheries Society Symposium 69.

Benville, P.E. Jr., and S. Korn. 1977. The acute toxicity of six monocyclic aromatic crude oil components to striped bass (*Morone saxatilis*) and bay shrimp (*Crangon franciscorum*). Calif. Fish Game 63: 204-209.

Bergey, L.L., R.A. Rulifson, M.L. Gallagher, and A.S. Overton. 2003. Variability of Atlantic Coast Striped Bass Egg Characteristics. North Amer. J. Fish. Manag. 23(2): 558-572.

Berlinsky, D.L., M.C. Fabrizio, J.F. O'Brien, and J.L. Specker. 1995. Age-at-maturity estimates for Atlantic coast female striped bass. Trans. Am. Fish. Soc. 124: 207-215.

Bernatchez, L., and M. Giroux. 2000. Les poissons d'eau douce du Québec et leur répartition dans l'Est du Canada. Broquet. 350 p.

Bernier, R. 1996. Relation entre la taille automnale et la survie hivernale de bar rayé (*Morone saxatilis*) de la rivière Miramichi. Thèse d'Initiation à la Recherche. Université de Moncton, Moncton, N.B. 24 p.

Bologna. P.A.X. 2007. Impacts of differential predation potential on Eel Grass (Zostera marina) faunal community structure. Aquatic Ecology 41(2): 221-229.

Bonn, E.W., W.M. Bailey, J.D. Bayless, K.E. Erickson, and R.E. Stevens (ed.). 1976. Guidelines for striped bass culture. American Fisheries Society, Striped Bass Committee of the Southern Division. 103 p.

Boynton, W.R., T.T. Polgar, and H.H. Zion. 1981. Importance of juvenile Striped bass food habits in the Potomac estuary. Trans. Am. Fish. Soc. 110(1): 56-63.

Bradford, R.G., and G. Chaput. 1996. Status of striped bass (*Morone saxatilis*) in the southern Gulf of St. Lawrence in 1995. DFO Atl. Fish. Res. Doc. 96/62: 36 p.

Bradford, R.G., and G. Chaput. 1998. Status of striped bass (*Morone saxatilis*) in the Gulf of St. Lawrence in 1997. DFO CSAS Res. Doc. 98/35: 25 p.

Bradford, R.G., G. Chaput, S. Douglas, and J. Hayward. 2001. Status of striped bass (*Morone saxatilis*) in the Gulf of St. Lawrence in 1998. DFO CSAS Res. Doc. 2001/006: iii + 30 p.

Bradford, R.G., E. Tremblay, and G. Chaput. 1997a. Winter distribution of striped bass (*Morone saxatilis*) and associated environmental conditions in Kouchibouguac National Park during 1996-1997. Parks Canada – Eco. Monit. Data Rep. 003: iv + 59 p.

Bradford, R.G., G. Chaput, T. Hurlbut, and R. Morin. 1997b. By-catch of striped bass, white hake, winter flounder, and Atlantic tomcod in the autumn "open water" smelt fishery of the Miramichi River estuary. Can. Tech. Rep. Fish. Aquat. Sci. 2195: vi + 37 p.

Bradford, R.G., G. Chaput, and E. Tremblay. 1995. Status of striped bass (*Morone saxatilis*) in the Gulf of St. Lawrence. DFO Atl. Fish. Res. Doc. 95/119: 43 p.

Bradford, R.G., and P. Leblanc. 2011. Update Status Report on Bay of Fundy Striped bass (*Morone saxatilis)*. Canadian Science Advisory Secretariat. Working Paper 2011/XXX. 53 p.

Bradford, R.G., P. LeBlanc, and P. Bentzen. 2012. Update Status Report on Bay of Fundy Striped Bass (Morone saxatilis). DFO Can. Sci. Advis. Sec. Sci. Res. Doc. Rep. 2012/021: vi + 46p.

Brousseau, J. 1955. Régime alimentaire du Bar (*Roccus saxatilis*) du fleuve Saint-Laurent (Kamouraska, Rivière-Ouelle, Montmagny). Brief for the l'école supérieure des pêcheries, La Pocatière, Quebec. 42 p.

Bujold, J.N., and M. Legault. 2012. Comportement spatio-temporel de la population réintroduite de bars rayés (*Morone saxatilis*) dans le fleuve St-Laurent (Rapport d'étape). Ministère des Ressources naturelles et de la Faune, Direction générale de l'expertise sur la faune et ses habitats, Direction de la faune aquatique, Québec. 55 p. Preliminary Report.

Bulak, J.S., J.S. Crane, D.H. Secor, and J.M. Dean. 1997. Recruitment dynamics of striped bass in the Santee-Cooper system, South Carolina. Trans. Am. Fish. Soc. 126(1): 133-143.

Cairns, D.K., J.-D. Dutil, S. Proulx, J.D. Mailhiot, M.-C. Bédard, A. Kervella, L.G. Godfrey, E.M. O'Brien, S.C. Daley, E. Fournier, J.P.N. Tomie, and S.C. Courtenay. 2012. An atlas and classification of aquatic habitat on the east coast of Canada, with an evaluation of usage by the American eel. Can. Tech. Rep. Fish. Aquat. Sci. No. 2986: v + 103 p.

Canadian Endangered Species Conservation Council. 2006. Wild Species 2005: The General Status of Species in Canada. http://www.wildspecies.ca/wildspecies2005/index.cfm?lang=e (Accessed April 12, 2011).

Canadian Rivers Institute. 2011. The Saint John River: A State of the Environment Report. Canadian Rivers Institute, University of New Brunswick. 175 p. (http://www.unb.ca/research/institutes/cri/_resources/pdfs/criday2011/cri_sjr_soe_final.pdf)

Chadwick, H.K., D.E. Stevens, and L.W. Miller. 1977. Some factors regulating the striped bass population in the Sacramento-San Joaquin Estuary, California. Pp. 18-35, in Van Winkle, W. (ed.). 1977. Proceedings of the conference on assessing the effects of power-plant-induced mortality on fish populations, Gatlinburg, Tennessee. Pergamon Press, N.Y.

Chaput, G., and R.G. Randall. 1990. Striped bass (*Morone saxatilis*) from the Gulf of St. Lawrence. DFO CAFSAC Res. Doc. 90/71: 29 p.

Chaput. G., and S. Douglas. 2011. Hierarchical Bayesian Model to Estimate the Spawning Stock of Striped Bass in the Northwest Miramichi River, 1994 to 2010. CSAS Working Paper. 62 p.

Chittenden, M.E. 1971. Status of the striped bass, *Morone saxatilis*, in the Delaware River. Chesapeake Sci. 12(3): 131-136.

Comité aviseur sur la réintroduction du bar rayé. 2001. Plan d'action pour la réintroduction du bar rayé (*Morone saxatilis*) dans l'estuaire du Saint-Laurent. Société de la Faune et des parcs du Québec. Direction du développement de la faune. 41 p.

Comeau. S. 2008. Activity Report. Natua'quanek First Nation Striped Bass and American Eel Assessment Project. 6 p.

Cook, A.M. 2003. Growth and survival of age 0+ Shubenacadie River striped bass (*Morone saxatilis*) in relation to temperature and salinity. MSc thesis, Nova Scotia Agricultural College, Truro.

Cook., A.M., J. Duston, and R.G. Bradford. 2010. Temperature and Salinity Effects on Survival and Growth of Early Life Stage Shubenacadie River Striped Bass. Trans. Am. Fish. Soc. 139(3): 749-757.

Cook., A.M., J. Duston, and R.G. Bradford. 2006. Thermal tolerance of a northern population of striped bass *Morone saxatilis*. Journal of Fish Biology 69: 1482-1490.

Cooper, J.C., and T.T. Polgar. 1981. Recognition of year-class dominance in striped bass management. Trans. Am. Fish. Soc. 110(1): 180-187.

COSEWIC. 2004. COSEWIC Assessment and Status Report on the Striped Bass (*Morone saxatilis*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 43 p. (www.sararegistry.gc.ca/Status/Status_e.cfm).

COSEWIC. 2010a. COSEWIC Guidelines on Manipulated Populations. Appendix E7. COSEWIC Operations and Procedures Manual. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2010b. COSEWIC assessment and status report on the Atlantic Salmon Salmo salar (Nunavik population, Labrador population, Northeast Newfoundland population, South Newfoundland population, Southwest Newfoundland population, Northwest Newfoundland population, Quebec Eastern North Shore population, Quebec Western North Shore population, Anticosti Island population, Inner St. Lawrence population, Lake Ontario population, Gaspé-Southern Gulf of St. Lawrence population, Eastern Cape Breton population, Nova Scotia Southern Upland population, Inner Bay of Fundy population, Outer Bay of Fundy population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xlvii + 136 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

Côté, C.L. 2012. Caractérisation de l'habitat utilisé par les larves et les juvéniles issus de la nouvelle population de bars rayés de l'estuaire du Saint-Laurent sur la rive sud entre Montmagny et Rivière-Ouelle durant la saison de croissance 2011. Ministère des Ressources Naturelles et de la Faune, Direction de l'expertise Faune-Forêts-Territoire, Direction générale du Bas-Saint-Laurent. 60 p.

Coutant, C.C. 1985. Striped bass, temperature, and eutrophication: a speculative hypothesis for environmental risk. Trans. Am. Fish. Soc. 114(1): 31-61.

Cox, P. 1893. Observations on the distribution and habits of some New Brunswick fishes. Bull. Nat. Hist. Soc. of New Brunswick 11: 33-42.

Cuerrier, J.P. 1962. Inventaire biologique des poissons et des pêcheries de la région du lac Saint-Pierre. Naturaliste can., 89: 193-214.

Dadswell, M.J. 1976. Notes on the biology and research potential of striped bass in the Saint John estuary. In Baseline survey and living resource potential study of the Saint John River Estuary. Vol. III, Fish and Fisheries. Huntsman Marine Lab., St. Andrews, N.B. 105 p.

Dadswell, M.J. 1983. Commercial fisheries of the Saint John Harbour, New Brunswick, Canada, 1875-1983: Estuarine fishes. Environ. Protec. Serv. Tech. Rep. 14 p.

Dadswell, M.J., and R.A. Rulifson. 1994. Macrotidal estuaries: a region of collision between migratory marine animals and tidal power development. Biological Journal of the Linnean Society 51: 93-113

Dadswell, M.J., R. Bradford, A.H. Leim, D.J. Scarratt, G.D. Melvin, and R.G. Appy. 1984. A review of research on fishes and fisheries in the Bay of Fundy between 1976 and 1983 with particular reference to its upper reaches. *In*: Gordon, D.C., and M.J. Dadswell. 1984. Update on the marine environmental consequences of tidal power development in the upper reaches of the Bay of Fundy. Can. Tech. Rep. Fish. Aquat. Sci. 1256: vii + 686 p.

Dahlberg, M.D. 1979. A review of survival rates of fish eggs and larvae in relation to impact assessment. Mar. Fish. Rev. 41(3): 1-12.

Dew, C.B. 1988. Stomach contents of commercially caught Hudson River striped bass, *Morone saxatilis*, 1973-75. Fish. Bull. 86(2): 397-401.

Dey, W. P. 1981. Mortality and growth of young-of-the-year striped bass in the Hudson River Estuary. Trans. Am. Fish. Soc. 110: 151-157.

DFO. 2006. Recovery Potential Assessment for the St. Lawrence River, Southern Gulf of St. Lawrence and Bay of Fundy Striped Bass (*Morone saxatilis*) Populations. DFO Can. Sci. Adv. Secr., Science Advisory Report 2006/053.

DFO. 2010a. Potential Impact of Accidental Captures by Commercial and Recreational Fisheries on the Survival and Recovery of the Striped Bass (*Morone saxatilis)* Population in the St. Lawrence River. DFO Can. Sci. Advi. Secr., Science Response 2009/018.

DFO. 2010b. Proceedings of the Quebec Region Science Advisory Process on the Assessment of Habitat Quality and Habitat Use by the Striped Bass (*Morone saxatilis*) Population of the St. Lawrence River, Quebec. April 13, 2010. DFO Can. Sci. Adv. Secr., Proceedings Series 2010/035.

DFO. 2010c. Assessment of Habitat Quality and Habitat Use by the Striped Bass (*Morone saxatilis)* Population of the St. Lawrence River, Quebec. DFO Can. Sci. Adv. Secr., Science Advisory Report 2010/069.

DFO. 2011. Allowable harm assessment of Striped Bass (Morone saxatilis) in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/014.

Diaz, M., G.M. Leclerc, and B. Ely. 1997. Nuclear DNA markers reveal low levels of genetic divergence among Atlantic and Gulf of Mexico populations of striped bass. Trans. Am. Fish. Soc. 126: 163-165.

Diodati, P.J., and R.A. Richards. 1996. Mortality of striped bass hooked and released in salt water. Trans. Amer. Fish. Soc. 125: 300-307.

Douglas, S.G., G. Chaput, and R.G. Bradford. 2001. Status of striped bass (*Morone saxatilis*) in the southern Gulf of St. Lawrence in 1999 and 2000. DFO CSAS Res. Doc. 2001/058: 34 p.

Douglas, S.G., R.G. Bradford, and G. Chaput. 2003. Assessment of Striped Bass (*Morone saxatilis*) in the Maritime Provinces in the Context of Species at Risk. CSAS Res. Doc. 2003/008: iii + 49 p.

Douglas, S.G., G. Chaput, and D. Caissie. 2006. Assessment of Status and Recovery Potential for Striped bass (*Morone saxatilis*) in the Southern Gulf of St. Lawrence. CSAS Res. Doc. 2006/041. viii + 95 p.

Douglas, S.G., G. Chaput, J. Hayward, and J. Sheasgreen. 2009. Prespawning, spawning, and postspawning behaviour of striped bass in the Miramichi River. Trans. Am. Fish. Soc. 138(1): 121-134.

Douglas, S.G., and G. Chaput. 2011a. Information on the striped bass (*Morone saxatilis*) population of the southern Gulf of St. Lawrence relevant to the development of a 2nd COSEWIC status report for the species. DFO Can. Sci. Advis. Sec. Res. Doc 2011/098: iv+ 16 p.

Douglas, S.G., and G. Chaput. 2011b. Assessment and status of striped bass (*Morone saxatilis*) in the Southern Gulf of St. Lawrence 2006-2010. DFO Can. Sci. Advis. Sec. Res. Doc 2011/097: iv+ 22 p.

Dudley, R.G., and K.N. Black. 1978. Distribution of striped bass eggs and larvae in the Savannah River estuary. Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies. 32, 561-570.

Duston, J. 2010. Bay of Fundy Striped Bass Recreational Angler Survey, 2009. Dept. Plant and Animal Sciences, Nova Scotia Agricultural College (NSAC). 26 p.

Durham, M. 1980. Toxic chemicals may provide due to mysterious disappearance of striped bass. Fish and Wildl. Serv. News release. *In:* Northeast 36th (#8.2).

Faber, D.J. 1976. Hyponeustonic fish larvae in the Northumberland Strait during summer 1962. J. Fish Res. Board Can. 33: 1167-1174

Field, J.D. 1997. Atlantic striped bass management: Where did we go right?. Fisheries. 22(7): 6-8.

Freeman, L. 2012. Annapolis River 2011 annual water quality monitoring report. Clean Annapolis River Project (CARP). Available at http://www.annapolisriver.ca/

Gagné, N., A-M MacKinnon, L. Boston, B. Souter, M. Cook-Versloot, S. Griffiths, and G. Olivier. 2007. Isolation of viral haemorrhagic septicaemia virus from mummichog, stickleback, striped bass and brown trout in eastern Canada. Journal of Fish Diseases 30: 213-223.

Gagnon, M., Y. Ménard, and J.-F. La Rue. 1993. Caractérisation et évaluation des habitats du poisson dans la zone de transition saline du Saint-Laurent. Rap. Tech. Can. des sci. Halieut. aquat. 1920 : 104 p.

Gagnon, P., and G. Verreault. 2012. Validation de l'indice d'abondance des bars rayés juvéniles à la station de la Pointe de la Rivière Ouelle à l'automne 2011. Ministère des Ressources naturelles et de la Faune, Direction de l'expertise faune-Forêts-Territoire, Direction générale du Bas-Saint-Laurent. 54 p.

Gardinier, M.N., and T.B. Hoff. 1982. Diet of striped bass in the Hudson River Estuary. N.Y. Fish Game J. 29(2): 152-165.

Goodyear, C.P. 1985. Relationship between reported commercial landings and abundance of young striped bass in Chesapeake Bay, Maryland. Trans. Am. Fish. Soc. 114(1): 92-96.

Government of Canada. 2010. Order Acknowledging Receipt of the Assessments Done Pursuant to Subsection 23(1) of the Act. Species at Risk Act. Canada Gazette Part II 144(21): 1972-1974. Registration SI/2010-76.

Hall, L.W., Jr. 1991. A synthesis of water quality and contaminants data on early life stages of striped bass, *Morone saxatilis*. Rev. Aquat. Sci. 4(2-3): 261-288.

Hansen, A.R. (ed.) 2004. Status and Conservation of Eelgrass (*Zostera marina*) in Eastern Canada. Canadian Wildlife Service, Atlantic Region, Technical Report Series No.412. 40 p.

Harris, P.J., and R.A. Rulifson. 1988. Studies of the Annapolis River striped bass sport fishery, 1987. I. Creel survey. Report to Tidal Power Corporation, Halifax, Nova Scotia.

Harris. P.J. 1988. Characterization of the Striped Bass sport fishery in the Annapolis River, Nova Scotia. Department of Biology, November 1988. A Thesis Presented to the Faculty of the Department of Biology. East Carolina University. Degree Master of Science in Biology. 112 p.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Canada Bulletin 180: 740 p.

Hatin, D., S. Lachance, and D. Fournier. 2007. Effect of Dredged Sediment Deposition on Use by Atlantic Sturgeon and Lake Sturgeon at an Open-Water Disposal Site in the St. Lawrence Estuarine Transition Zone. American Fisheries Society Symposium 56: 235-255

Hogans, W.E. 1984. Helminths of striped bass (Morone saxatilis) from the Kouchibouguac River, New Brunswick. Journal of Wildlife Disease 20: 61-63.

Hogans, W.E., and G. Melvin. 1984. Kouchibouguac National Park Striped Bass (*Morone saxatilis* Walbaum) Fishery Survey. Aquatic Industries, Limited, P.O. Box 294, St. Andrews, N.B., 91 p.

Hooper, W.C. 1991. Striped bass management in New Brunswick. Pp. 29-40 in R.H. Peterson [ed.] Proceedings of a workshop on biology and culture of striped bass (*Morone saxatilis*) Can. Tech. Rep. Fish. Aquat. Sci. 1832: vi +66 p.

Hope, K.M., R.N. Casey, G.H. Groocock, R.G. Getchell, P.R. Bowser, and J.W. Casey. 2010. Comparison of Quantitative RT-PCR with Cell Culture to Detect Viral Hemorrhagic Septicemia Virus (VHSV) IVb Infections in the Great Lakes. Journal of Aquatic Animal Health 22: 50–61.

Humphries, E.T., and K.B. Cumming. 1973. An evaluation of striped bass fingerling culture. Trans. Am. Fish. Soc. 102(1): 13-20.

Hurst, T.P., and D.O. Conover. 1998. Winter mortality of young-of-the-year Hudson River striped bass (*Morone saxatilis*): size-dependent patterns and effects on recruitment. Can. J. Fish. Aquat. Sci. 55: 1122-1130.

Jessop, B.M. 1980. Creel survey and biological study of the striped bass fishery of the Annapolis River, 1978. Can. Ms Rep. Fish. Aquat. Sci. 1566, 29 p.

Jessop, B.M. 1990. The status of striped bass in Scotia-Fundy region. Can. Atl. Fish. Sci. Advis. Comm., Res. Doc. 90/36.

Jessop, B.M. 1991. The history of striped bass fishery in the Bay of Fundy. Pp. 13-21 in Proceedings of a workshop on biology and culture of striped bass (*Morone saxatilis*) Can. Tech. Rep. Fish. Aquat. Sci. 1832: vi +66 p.

Jessop, B.M. 1995. Update on striped bass status in Scotia-Fundy region and proposals for stock management. DFO Atl. Fish. Res. Doc. 95/8: 8 p.

Jessop, B.M., and W.G. Doubleday. 1976. Creel survey and biological study of the striped bass fishery of the Annapolis River, 1976. Fish. Mar. Serv. Dept Environ. Tech. Rep. Ser. MAR/T-76-8, 47 p.

Jessop, B.M., and C. Vithayasai. 1979. Creel surveys and biological studies of the striped bass fisheries of the Shubenacadie, Gaspareau and Annapolis Rivers, 1976. Ms Rep. Res. Br. Dept Fish. Oceans 1532, 32 p.

Joseph, V., A. Locke, and J.G. Godin. 2006. Spatial distribution of fishes and decapods in eelgrass (Zostera marina) and sandy habitats of a New Brunswick estuary, eastern Canada. Aquatic Ecology 40: 111-123

Karas, N. 1974. The complete book of the striped bass. Winchester Press, New York. 367 p.

Kernehan, R.J., M.R. Headrick, and R.E. Smith. 1981. Early life history of striped bass in the Chesapeake and Delaware Canal and vicinity. Trans. Am. Fish. Soc. 110(1): 137-150.

Klassen. G. 2010. Index of Biotic Integrity for eelgrass fish communities in Kouchibouguac National Park. Prepared for Kouchibouguac National Park. 64 p.

Koo, T.S.Y. 1970. The striped bass fishery in the Atlantic states. Ches. Sci. 11(2): 73-93.

Korn, S., and R. Earnest. 1974. Acute toxicity of twenty insecticides to striped bass, *Morone saxatilis*. Calif. Fish and Game 60(3): 128-131.

Leblanc, C.H., and G. Chaput. 1991. Landings of estuarine fishes of the Gulf of St. Lawrence 1917-1988. Can. Data Rep. Fish. Aquat. Sci. 842: 101 p.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer Jr. 1980. Atlas of North American freshwater fishes. North Carolina State Museum of Natural History (p. 576). 854 p.

Legault, M. 2012. Reproduction du bar rayé (*Morone saxatilis*) dans le bassin de la rivière du Sud (Montmagny). Ministère des Ressources naturelles et de la Faune, Direction de l'expertise sur la faune et ses habitats, Direction de la faune aquatique, Québec. 137 p. Preliminary Report.

Magnin, E., and G. Beaulieu. 1967. Le bar, *Roccus saxatilis* (Walbaum), du fleuve Saint-Laurent. Natur. Can. 94: 539-555.

Manooch, C.S. 1973. Food habits of yearling and adult striped bass, *Morone saxatilis* (Walbaum), from Albemarle Sound, North Carolina. Chesapeake Sci. 14: 73-86.

Mansueti, R.J. 1958. Eggs, larvae and young of the striped bass, *Roccus saxatilis*. Md. Dep. Res. Educ., Chesapeake Biol. Lab., Contrib. 112: 35 p.

Martin, F.D., D.A. Wright, J.C. Means, and E.M. Setzler-Hamilton. 1985. Importance of food supply to nutritional state of larval striped bass in the Potomac river estuary. Trans. Am. Fish. Soc. 114(1): 137-145.

May, R.C. 1974. Larval mortality in marine fishes and the important period concept. Pp. 3-19, in Blaxter, J.H.S. (ed.). 1974. The early life history of fish. Spinger-Verlag, New York.

McLean, M.F., and M.J. Dadswell. 2012. Long-Term Effects of the Annapolis Royal Tidal Turbine on Two Fish Populations. OEER Energy Symposium, Halifax, May 2012

Melvin, G.D. 1978. Racial investigations of striped bass (*Morone saxatilis* (Walbaum, 1772)) (Pisces: Percichthyidae) for three Canadian Atlantic Rivers: Saint John, Shubenacadie, Tabusintac. MSc thesis, Acadia University, Wolfville, N.S. 143 p.

Melvin, G.D. 1991. A review of striped bass, *Morone saxatilis*, population biology in eastern Canada. Pp. 1-11 in R.H. Peterson [ed.] Proceedings of a workshop on biology and culture of striped bass (*Morone saxatilis*) Can. Tech. Rep. Fish. Aquat. Sci. 1832: vi +66 p.

Merriman, D. 1941. Studies on the striped bass (*Roccus saxatilis*) of the Atlantic Coast. U.S. Fish Wildl. Serv., Fish Bull. 50: 1-77.

Millard, M.J., J.W. Mohler, A. Kahnle, and A. Cosman. 2005. Mortality associated with catch and release angling of striped bass in the Hudson River. North Amer. J. Fish. Manag. 25: 1533-1541.

Miller, P.E. 1977. Experimental study and modeling of striped bass egg and larval mortality. PhD thesis, Johns Hopkins University, Baltimore, Maryland.

Morgan, R.P., and V.J. Rasin. 1973. Effects of salinity and temperature on the development of eggs and larvae of striped bass and white perch. App. X to Hydrographic and ecological effects of enlargement of the Chesapeake and Delaware canal. Contract DACW-61-71-C-0062, U.S. Army Corps of Engineers, Philadelphia district. Natural Resources Institute Ref. 73-109.

Morgan, R.P., V.J. Rasin, and R.L. Copp. 1981. Temperature and salinity effects on development of striped bass eggs and larvae. Trans. Am. Fish. Soc. 110(1): 95-99.

NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer/ (Accessed April 12, 2011).

North, E. W., and E. D. Houde. 2003. Linking ETM physics, zooplankton prey, and fish early-life histories to white perch (*Morone americana*) and striped bass (*M. saxatilis*) recruitment success. *Marine Ecology Progress Series* 260:219-236.

Olsen, E.J., and R.A. Rulifson. 1992. Maturation and fecundity of Roanoke River - Albemarle Sound striped bass. Trans. Am. Fish. Soc. 121(4): 524-537.

Paramore, L.M. 1998. Age, growth, and life history characteristics of striped bass, *Morone saxatilis*, from the Shubenacadie-Stewiacke River, Nova Scotia. MSc thesis, East Carolina University, Greeneville, NC. 91 p.

Parker, W.R., and K.G. Doe. 1981. Studies on the reproduction of Striped bass (*Morone saxatilis* (Walbaum)) from the Annapolis River, Nova Scotia. Surveillance Rep. Environ. Protec. Serv. Lab. Ser. Div. EPS 5-AR-81-6, 89 p.

Pearson, J.C. 1938. The life history of the striped bass, or rockfish, *Roccus saxatilis* (Walbaum). U.S. Fish Wildl. Serv., Fish Bull. 49: 825-860.

Pelletier, A.-M. 2009. Premier portrait biologique de la nouvelle population de Striped bass (*Morone saxatilis*) du fleuve Saint-Laurent résultant des ensemencements effectués entre 2002 et 2008. Ministère des Ressources naturelles et de la Faune. Direction de l'expertise Faune-Forêts-Territoire du Bas-Saint-Laurent, Direction de l'expertise sur la faune et ses habitats. 55 p.

Pelletier, A.-M., G. Bourget, G. Verreault, R. Tardif, M. Legault, and D. Deschamps. 2009. Suivi de la réintroduction du bar rayé (*Morone saxatilis*) dans l'estuaire du Saint-Laurent – Bilan 2009.

Pelletier, A.-M., G. Verreault, G. Bourget, and J. Dussureault. 2010. Utilisation de l'habitat par les différents stades de développement de la population réintroduite de Striped bass (*Morone saxatilis*) de l'estuaire du Saint-Laurent. Ministère des Ressources naturelles et de la Faune du Québec, Direction de l'expertise Faune-Forêts-Territoire du Bas-Saint-Laurent, Direction générale du Bas-Saint-Laurent. 50 p.

Pelletier, A.-M., G. Bourget, M. Legault, and G. Verreault. 2011. Réintroduction du bar rayé (*Morone saxatilis)* dans le fleuve Saint-Laurent: bilan du rétablissement de l'espèce. Naturaliste Canadien 135(1): 79-85.

Perley, L.W. 2008. Annual Report- Striped bass Program. 6 p.

Plan Saint-Laurent. 2012. Registre de planification des activités de dragage. (http://planstlaurent.qc.ca/registreactivitesdragage/DredgingActivityList.aspx)

Polgar, T.T. 1982. Factors affecting recruitment of Potomac River striped bass and resulting implications for management. Pp. 427-442, in Estuarine comparisons: proceedings of the Sixth Biennial International Estuarine Research Conference, Gleneden Beach, Oregon, 1981. New York, Academic Press, New York. 709 p.

Powles, H. (Chairperson). 2003. Proceedings of the National Science Review Meeting on Species at Risk Issues, December 9-13, 2002, Halifax, Nova Scotia. Fisheries and Oceans Canada Canadian Science Advisory Secretariat Proceedings Series 2002/035. 62 p.

Rago, P.J., R.M. Dorazio, R.A. Richards, and D.G. Deuel. 1989. Emergency striped bass research study report. U.S. Fish and Wildlife Service and National Marine Fisheries Service. 54 p.

Raney, E.C. 1952. The life history of the striped bass, *Roccus saxatilis* (Walbaum). Bull. Bingham Oceanogra. Collect. Yale Univ. 14: 5-177.

Rawstron, R.R., T.C. Farley, H.K. Chadwick, G.E. Delisle, D.B. Odenweller, D.E. Stevens, D. Kohlhorst, L. Miller, A. Pickard, and H. Reading. 1989. Striped bass restoration and management plan for the Sacramento-San Joaquin estuary. Phase I. California Department of Fish and Game. 39 p.

Ricker, W. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191. 382 p.

Robichaud-LeBlanc, K.A., S.C. Courtenay, and J.M. Hanson. 1997. Ontogenetic diet shifts in age-0 striped bass, *Morone saxatilis*, from the Miramichi River estuary, Gulf of St. Lawrence. Canadian Journal of Zoology 75(8): 1300-1309.

Robichaud-LeBlanc, K.A., S.C. Courtenay, and A. Locke. 1996. Spawning and early life history of a northern population of striped bass (*Morone saxatilis*) in the Miramichi River estuary, Gulf of St. Lawrence. Can. J. Zool. 74: 1645-1655.

Robichaud-LeBlanc, K.A., S.C. Courtenay, and T.J. Benfey. 1998. Distribution and Growth of Young-of-the-Year Striped Bass in the Miramichi River Estuary, Gulf of St. Lawrence. Trans. Am. Fish. Soc. 127: 56–69.

Robinson, M.R. 2000. Early life history movements, and genetic differentiation of young-of-the-year striped bass (*Morone saxatilis*) in the southern Gulf of St. Lawrence, New Brunswick. MSc thesis, University of New Brunswick, Fredericton, N.B. 172 p.

Robinson, M., S. Courtenay, T. Benfey, L. Maceda, and I. Wirgin. 2004. Origin and Movements of Young-of-the-Year Striped Bass in the Southern Gulf of St. Lawrence, New Brunswick. Trans. Am. Fish. Soc. 133(2): 412–426.

Robitaille, J.A. 1999. Rétablissement du bar rayé dans le Saint-Laurent: évaluation préliminaire des possibilites et des contraintes. Ministère de l'Environnement et de la Faune, Quebec, 68 p.

Robitaille, J.A. 2001. Biologie et exploitation de la population disparue de bar rayé du Saint-Laurent. Québec, Bureau d'écologie appliquée, Fondation de la Faune du Québec, Société de la faune et des parcs du Québec. 80 p.

Robitaille, J. 2005. Caractérisation de l'habitat des juvéniles de la population disparue de bar rayé *(Morone saxatilis)* du Saint-Laurent à partir de spécimens en collection. Programme d'intendance de l'habitat des espèces en péril (Canada), Fondation de la faune du Québec, Fondation Héritage Faune, Société de la faune et des Parcs du Québec, Bureau d'écologie appliquée, Fédération québécoise de la faune. 65 p.

Robitaille, J. 2010. Évaluation de la qualité de l'habitat et de son utilisation par la population disparue de bar rayé (*Morone saxatilis*) de l'estuaire du Saint-Laurent, Québec. DFO Can. Sci. Adv. Secr. Res. Doc. 2010/052, vi + 22 p.

Robitaille, J.A., Y. Vigneault, G. Shooner, C. Pomerleau, and Y. Mailhot. 1988. Modifications physiques de l'habitat du poisson dans le Saint-Laurent de 1945 à 1984 et effets sur les pêches commerciales. Can. Tech. Rep. Fish. Aquat. Sci. 1608: 45 p.

Robitaille, J. A., and I. Girard. 2002. Observations sur le bar rayé (*Morone saxatilis*) du Saint-Laurent recueillies auprès de pêcheurs témoins de sa disparition. Quebec, Fondation Héritage Faune, Bureau d'écologie appliquée, Société de la faune et des parcs du Québec: 43 p.

Robitaille, J., M. Bérubé, A. Gosselin, M. Baril, J. Beauchamp, J. Boucher, S. Dionne, M. Legault, Y. Mailhot, B. Ouellet, P. Sirois, S. Tremblay, G. Trencia, G. Verreault, and D. Villeneuve. 2011. Recovery Strategy for the Striped Bass (*Morone saxatilis),* St. Lawrence Estuary Population, Canada. *Species at Risk Act Recovey Strategy Series.* Ottawa: Fisheries and Oceans Canada. xi + 51 p.

Rogers, B.A., D.T. Westin, and S.B. Saila. 1977. Life stage duration studies on Hudson river striped bass. Univ. Rhode Island, Appl. Mar. Res. Group, NOAA Sea Grant Mar. Tech. Rep. 31: 111 p.

Rogers, B.A., and D.T. Westin. 1981. Laboratory studies on effects of temperature and delayed initial feeding on development of striped bass larvae. Trans. Amer. Fish. Soc. 110: 100-110

Rulifson, R.A., and M.J. Dadswell. 1995. Life history and population characteristics of striped bass in Atlantic Canada. Trans. Am. Fish. Soc. 124(4): 477-507.

Rulifson, R.A., and S.A. McKenna. 1987. Food of striped bass in the upper Bay of Fundy, Canada. Trans. Am. Fish. Soc. 116(1): 119-122.

Rulifson, R.A., S.A. McKenna, and M. Gallagher. 1987. Tagging studies of striped bass and river herring in upper Bay of Fundy, Nova Scotia. North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries, Morehead City, NC, ICMR Tech. Rep. 87-02: 175 p.

Rulifson, R.A., and K.A. Tull. 1999. Striped bass spawning in a tidal bore river: the Shubenacadie estuary, Atlantic Canada. Trans. Am. Fish. Soc. 128(4): 613-624.

Rulifson, R.A., S.A. McKenna, and M.J. Dadswell. 2008. Intertidal Habitat Use, Population Characteristics, Movement, and Exploitation of Striped Bass in the Inner Bay of Fundy, Canada. Trans. Am. Fish. Soc. 137(1): 23-32.

Rutherford, E.S., and E.D Houde. 1995. The influence of temperature on cohort-specific growth, survival, and recruitment of striped bass, *Morone saxatilis*, larvae in Chesapeake Bay. Fish. Bull. U.S. 93: 315-332.

Rutherford, E.S., E.D. Houde, and R.M. Nyman. 1997. Relationship of larval-stage growth and mortality to recruitment of striped bass, *Morone saxatilis*, in Chesapeake Bay. Estuaries 20: 174-198.

Scott, W.B., and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada, Bulletin 184, 966 p.

Scott, W.B., and M.G. Scott. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 p.

Scruggs, G.D. 1957. Reproduction of resident striped bass in Santee-Cooper reservoir, South Carolina. Trans. Am. Fish. Soc. 85: 144-159.

Secor, D.H. 2000. Longevity and resilience of Chesapeake Bay striped bass. ICES Journal of Marine Science 57(4): 808-815.

Secor, D.H., and E.D. Houde. 1995. Larval mark-release experiments: Potential for research on dynamics and recruitment in fish stocks. Pp. 423-445, in Secor, D.H., S.E. Campana and J.M. Dean (eds.). Recent Developments in Fish Otolith Research. Belle W. Baruch Library in Marine Sciences Number 19. University of South Carolina Press, Columbia, S.C. 735 p.

Setzler, E.M., W.R. Boynton, K.V. Wood, H.H. Zion, L. Lubbers, N.K. Mountford, P. Frere, L. Tucker, and J.A. Mihursky. 1980. Synopsis of biological data on striped bass, *Morone saxatilis* (Walbaum). NOAA Tech. Rep., NMFS Circ. 433. 69 p.

Setzler-Hamilton, E.M., W.R. Boynton, J.A. Mihursky, T.T. Polgar, and K.V. Wood 1981. Spatial and temporal distribution of striped bass, eggs, larvae and juveniles in the Potomac estuary. Trans. Am. Fish. Soc. 110: 121-136.

Shannon, E.H., and W.B. Smith. 1967. Preliminary observations on the effect of temperature on striped bass eggs and sack fry. Proc. 21st Annu. Conf. Southeast. Assoc. Game Fish. Comm., pp. 257-260.

Stokesbury, K.D.E. 1987. Downstream migration of juvenile alosids and an estimate of mortality caused by passage through the Straflo low-head hydroelectric turbine at Annapolis Royal, Nova Scotia. MSc thesis, Acadia University, Wolfville, Nova Scotia.

Talbot, G.B. 1966. Estuarine environmental requirements and limiting factors for striped bass. Pp. 37-49, in A symposium on estuarine fisheries. Am. Fish. Soc. Spec. Publi. 3, 154 p.

Thistle. M.E. 2011. Presence and distribution of young-of-the-year striped bass (Morone saxatilis) throughout rivers and estuaries of the southern Gulf of St. Lawrence, summer 2011. Department of Fisheries and Oceans. 40 p.

Tidemarsh, W.G. 1984. Assessing the Environmental Impact of the Annapolis Tidal Power Project. Water Sci. and Technol. 16: 307-317.

Tremblay, V. 2004. Stratégie de reproduction de l'anguille d'Amerique (*Anguilla rostrata*) chez cinq sous-populations dans le bassin hydrographique du fleuve Saint-Laurent. Master's thesis, Université du Québec à Rimouski, Rimouski, 50 p.

Tremblay, V. 2009. Reproductive strategy of female American Eel (*Anguilla rostrata)* among five subpopulations in the St. Lawrence River watershed. Pp. 85-102, in J.M. Casselman and D.K. Cairns (eds.). Eels at the edge: science, status, and conservation concerns. American Fisheries Society, Symposium 58, Bethesda, Maryland.

Trent, L., and W.W. Hasler. 1966. Feeding behavior of adult striped bass, *Roccus saxatilis*, in relation to stages of sexual maturity. Chesapeake Sci. 7(4): 189-192.

Trépanier, S., and J.A. Robitaille. 1995. Rapport sur la situation de certaines populations indigènes de bar rayé (*Morone saxatilis*) au Québec et au Canada. Ministère de l'Environnement et de la Faune, Direction de la Faune et des Habitats. Quebec, Ministère de l'Environnement et de la Faune, Direction de la Faune et des Habitats. 61 p.

Ulanowicz, R.E., and T.T. Polgar. 1980. Influence of anadromous spawning behavior and optimal environmental conditions upon striped bass (*Morone saxatilis*) year-class success. Can. J. Fish. Aquat. Sci. 37(2): 143-154.

Van den Avyle, M.J., and M.A. Maynard. 1994. Effects of saltwater intrusion and flow diversion on the reproductive success of striped bass in the Savannah River estuary. Trans. Am. Fish. Soc. 123: 886-903.

Van Winkle, W., B.L. Kirk, and B.W. Rust. 1979. Periodicities in Atlantic Coast striped bass (*Morone saxatilis*) commercial fisheries data. J. Fish. Res. Bd. Can. 36: 54-62.

Vladykov, V.D. 1945. Rapport du biologiste du Département des pêcheries. Pp. 51-52, in Rapp. Gén. Min. Chasse et Pêcheries. Prov. Québec pour 1944.

Vladykov, V.D. 1947. Rapport du biologiste du Département des pêcheries. Pp. 44-61, in Rapp. Gén. Min. Chasse et Pêcheries. Prov. Québec pour 1946-47 contr. 22.

Vladykov, V.D. 1953. Rapport du laboratoire de limnologie. Contr. Dép. Pêcheries, Quebec. 41: 60-68.

Vladykov, V.D., and J. Brousseau. 1957. Croissance du bar d'Amérique, *Roccus saxatilis*, dans le Québec. Dépt des pêcheries, Quebec. Typed manuscript, 8 p.

Waldman, J.R., D.J. Dunning, Q.E. Ross, and M.T. Mattson. 1990. Range dynamics of Hudson River Striped Bass along the Atlantic coast. Trans. Am. Fish. Soc. 119: 910-919.

Waldman, J.R., J. Grossfield, and I. Wirgin. 1988. Review of stock discrimination techniques for striped bass. North American Journal of Fisheries Management 8: 410-425.

Walter, J.F. III, A.S. Overton, K.H. Ferry, and M.E. Mather. 2003. Atlantic coast feeding habits of striped bass: a synthesis supporting a coast-wide understanding of trophic biology. Fisheries Management and Ecology 10: 349-360.

Weldon, J., S. Courtenay, and D. Garbary. 2007. The Community Aquatic Monitoring Program (CAMP) for measuring Marine Environmental Health in Coastal Waters of the southern Gulf of St. Lawrence: 2005 Overview. Can. Tech. Rep. Fish. Aquat. Sci. 2708: viii + 47 p.

Weldon, J., S. Courtenay, and D. Garbary. 2008. The Community Aquatic Monitoring Program (CAMP) for measuring Marine Environmental Health in Coastal Waters of the southern Gulf of St. Lawrence: 2007 Overview. Can. Tech. Rep. Fish. Aquat. Sci. 2825: viii + 75 p.

Wilber, D. H., and D. G. Clarke. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21:855–875.

Wilde, G.R., M. Muoneke, P. Bettoli, K. Nelson, and B. Hysmith. 2000. Bait and temperature effects on striped bass hooking mortality in freshwater. North Amer. J. of Fish. Manag. 20: 810-815.

Williams, R.R.G. 1978. Spawning of the striped bass, *Morone saxatilis* (Walbaum), in the Annapolis river, Nova Scotia. MSc thesis, Acadia University, Wolfville, N.S. 164 p.

Williams, R.R.G., G.R. Daborn, and B. Jessop. 1984. Spawning of the striped bass (*Morone saxatilis*) in the Annapolis River, Nova Scotia. Proc. N.S. Inst. Sci. 34: 15-23.

Williamson, F.A. 1974. Population studies of striped bass (*Morone saxatilis*) in the Saint John and Annapolis rivers. MSc thesis, Acadia University, Wolfville, N.S. 60 p.

Wirgin, I.I., B. Jessop, S. Courtenay, M. Pedersen, S. Maceda, and J.R. Waldman. 1995. Mixed-stock analysis of striped bass in two rivers of the Bay of Fundy as revealed by mitochondrial DNA. Can. J. Fish. Aquat. Sci. 52: 961-970.

Wirgin, I.I., T.L. Ong, L. Maceda, J.R. Waldman, D. Moore, and S. Courtenay. 1993. Mitochondrial DNA Variation in Striped Bass (*Morone saxatilis*) from Canadian Rivers. Can. J. Fish. Aquat. Sci. 50: 80-87.

ZIP (Zone d'intervention prioritaire Baie des Chaleurs). 2010. Projet d'acquisition de connaissances sur l'habitat du bar rayé (*Morone saxatilis*) dans le secteur de la baie des Chaleurs dans le but de supporter la conservation et la protection de l'espèce. Activity Report, Permit No. SG-NBT-10-069: 13 p.

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Valérie Tremblay is an aquatic wildlife biologist with AECOM (2 Fusey Street, Trois-Rivières, QC G8T 2T1). She has 12 years of experience in this field. At AECOM, her work is focused on performing characterizations and environmental assessments related to the aquatic environment and fish habitat. She has also participated in a number of contracts to assess the potential presence of species at risk. With the help of the Canadian Eel Science Working Group (CESWoG), she wrote the first report on the status of the American Eel (*Anguilla rostrata*) in Canada for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and, in 2010, drafted the update status report. Ms. Tremblay has the necessary expertise to document and analyze relevant data on species at risk, such as Striped Bass. She is a collaborative member of Ocean Tracking Network group undertaking research for American eel and Striped Bass with the St. Lawrence (Laval University, Fisheries and Oceans Canada, MRNF, and AECOM).

Jean-François Bourque has a bachelor's degree in biology and a master's degree in aquatic ecology. With his diversified experience, he has become a specialist in studies on freshwater aquatic ecology. Mr. Bourque joined AECOM in May 2006 after working for several years for Dr. Julian Dodson at Université Laval, where he conducted a number of projects on the fish communities of the St. Lawrence River and its middle estuary. He was the biologist in charge of the Centre interuniversitaire de recherche sur le saumon atlantique (CIRSA) for four years and worked actively on various aspects of the biology of salmonids. Since joining AECOM, where he is currently project director, he has been involved in a number of projects on fish, including one on the behaviour of Striped Bass in a thermal plume from the Gentilly nuclear power plant. He has also contributed to a number of scientific papers and popular articles on fish. Mr. Bourque is also part of Ocean Tracking Network group undertaking research for American eel and Striped Bass with the St. Lawrence.

COLLECTIONS EXAMINED

Not applicable.